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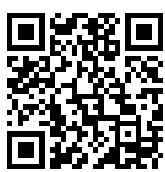

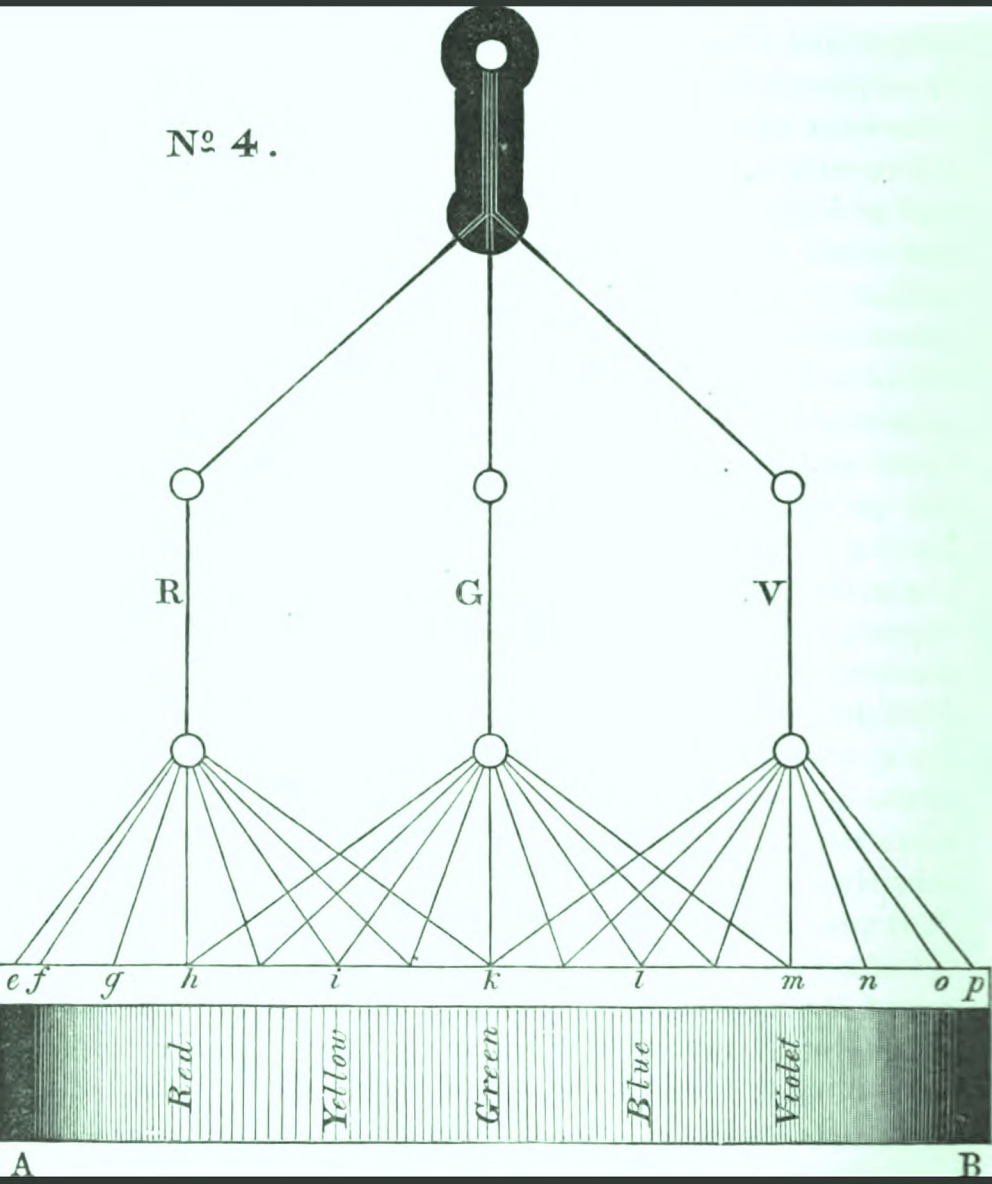

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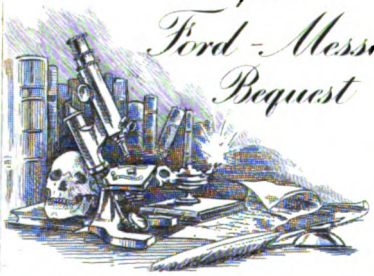

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TRANSACTIONS

OF THE

ROYAL SCOTTISH SOCIETY

OF

ARTS.

VOL. VIII.

EDINBURGH
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TRANSACTIONS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS.

An Address on Technical Education. By Professor Fleeming Jenkin, F.R.SS.L. & E.*

The resolutions arrived at by the Conference on Technical Education, and the able address of your President, prove that this Society is fully alive to the necessity for improved scientific instruction throughout the country. I will not, therefore, detain you with any arguments upon general principles which have been affirmed by every class of society, but taking it for granted that we are all of one mind in believing that the education of our artisans, our manufacturers, and our engineers should be improved by the improved and extended teaching of science, I purpose to-night to confine myself chiefly to practical suggestions of steps which I think might be immediately taken towards the object which we have all in view.

I well know the difficulty and danger of making practical suggestions. The man who confines himself to general principles, and the critic who assails existing abuses, is sure to carry a large portion of his audience with him. The abuses are often palpable, and the general truths soon become popular truisms; but the man who brings forward new proposals for definite action, cannot and ought not to expect

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* Read before the Society 11th January 1869.

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an equally ready adhesion to his schemes. They must in their turn run the gauntlet of criticism, and be subject to many successive amendments, before any large body will consent to put them in practice; but a man who will thus subject himself to criticism, with the object of attaining an avowedly good end, may at least ask for an indulgent hearing before the criticism begins, and this indulgence I ask from you to-night.

Probably the general improvement in the scientific education of the community at large can only be effected by the adoption of some such scheme as that proposed by the Schools Inquiry Commission, having for its result a complete system of schools of different grades under local management, but subject to general regulations laid down by a department of the government. The Commission have shown how the necessary funds for such a system can be obtained, and have proposed a definite scheme for the administration of these funds. If schools, of several grades systematically arranged, were once established, it would be an easy matter to insist on the introduction into a given number of each grade such distinctly scientific training as would warrant the appellation of science schools, as distinguished from classical schools, and results would soon show whether science does or does not afford an excellent material for mental culture, besides that merely useful information which it is not the chief object of education to impart. If a system of graded schools existed, we could apply towards their improvement the masses of information which have been collected as to foreign courses of study. Now, even when we know our own wishes, what bodies are we to attack? It is hopeless to expect that a successful experiment on any great scale can be made so long as the schools of the country are under an infinite number of different trustees, corporations, and committees wholly incapable of combined action. I do not purpose to-night to examine the proposals of the Commission, but will direct your attention, in connection with this part of the subject, to the report of the Sub-Committee on Technical Education appointed by the London Society of Arts.

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I fear, however, that we shall have to wait some years before a complete system of graded schools can be established; and it is most desirable that even if a complete system of scientific instruction cannot be created offhand, something should be done to remedy our deficiencies at once. I will, therefore, make a few suggestions as to means by which the scientific education of artisans and foremen, on the one hand, and manufacturers and engineers, on the other hand, might be improved under existing institutions.

Workmen and teachers of workmen now receive some scientific instruction from teachers in schools, assisted by the Science and Art Department of the Committee of Council on Education; and in the Report for 1866, on Science Schools and Classes, Captain Donnelly says, that "the various modifications and enlargements made from time to time in the system of aid to science instruction have now rendered it a system which may fairly be said to meet the requirements of the country, as far as elementary science is concerned." From that assertion I most thoroughly dissent, but I am not prepared to join the ranks of those who think that no good thing can come out of South Kensington. South Kensington has done something for elementary scientific instruction; it has established a system of examinations and rewards, which have stimulated the study of the elements of science. Although I do not approve of all that has been done, although I think that much remains to be done, I will not therefore refuse such assistance as is given, but will rather endeavour to state how I think the value of that assistance can be greatly increased and the sphere of its action greatly enlarged. If therefore, in what I am about to say, I criticise freely the acts of the Science and Art Department, I beg you will consider that the criticism is not hostile, but is made with a view to the improvement, not to the injury, of the department.

Now, I will draw your attention to what has been done by the department in support of mechanical drawing, and you will thus understand better why I dissent from Captain Donnelly's opinion that the system meets the requirements of the country. I choose mechanical drawing, because I

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think that a knowledge of the elements of this art is the most useful of all to the workman. Why do we think reading, writing, and arithmetic so useful and essential? Because, without a knowledge of these, little accurate knowledge of any kind can be acquired. These are the tools we put into all men's hands with which to work at the mine of learning, and the knowledge of mechanical drawing is almost as essential a tool as the three others for the working man. Without a knowledge of this art he cannot represent his own mechanical ideas; worse still, he cannot understand the ideas of others, which he is called upon in his business, as a mason, mechanic, carpenter, joiner, fitter, erecter, and so forth, to carry out; perhaps, worst of all, he is debarred from learning any of the principles of his special business from books or journals, because he cannot understand the diagrams. So true is this that most skilled artisans and all foremen do contrive, after infinite labour, somehow to pick up such a knowledge of drawing as allows them to understand the simpler representations of machinery and construction. Not a few teach themselves how to draw a little; but they have to teach themselves, or at least to learn in little classes, where the appliances and assistance received is almost pitiable. The men requiring this knowledge are the whole class of skilled workmen; and so important is this knowledge to them that the French Government Commission on Technical Education came to the conclusion, that for the working classes technical education meant *instruction in mechanical drawing;* and I entirely agree with this conclusion, because, as I have said before, it is a tool or key with which the able and energetic can for themselves open fresh paths to knowledge, and because experience has shown that it can be taught, and taught successfully, to men who have only learnt how to write, read, and cipher.

Which is really the most important to the working classes in Great Britain, such a power of representing objects by free-hand drawing, as can be given to workmen, coupled with such an appreciation of the fine arts as they can be expected to acquire; or the power of representing the elements of machinery and constructive details, coupled

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with the power of understanding the representation of mechanism and structures?

The first branch of knowledge will be useful to all those classes engaged in the design and execution of artistic produce. The second branch of knowledge will be useful to all engaged with those productions which require the use of machinery or structures. Can we doubt which is the most important class in England or in any country? The whole agricultural population of this country, and the whole manufacturing population except the artists, using this word in its largest sense, require a knowledge of mechanical drawing, and the artists would be the better for having it.

Now, let us compare what government does for mechanical drawing, as compared with artistic drawing—for art as compared with science.

There are 99 government schools of art in which free-hand drawing is taught, and aid is given to 560 other schools. 17,210 students learn free-hand drawing in the government schools; and altogether, in 1866, 105,695 were taught drawing through the agency of the department—an admirable result, and one which probably does meet the requirements of the people. 2306 teachers were examined, and 1583 of these obtained certificates of competency. Turning to mechanical drawing, the contrast is very great. 16 teachers were examined, and 13 passed. 13 as compared with 1583 for free-hand drawing. 20 schools receive some assistance, because they give some instruction in mechanical drawing. 20 as compared with nearly 700 for free-hand drawing. The total number of persons receiving instruction in mechanical drawing in Great Britain and Ireland is 1207. This is the number we must contrast with 106,000 taught free-hand drawing. Lastly, turning to the payments for results, we find L.34,851 paid to encourage free-hand drawing, and about L.340 paid for the encouragement of mechanical drawing. I ask, Does this proportion of one hundred to one correspond to the relative importance of artistic and scientific drawing? Is this sum of L.340 such a sum as can fairly be said to encourage mechanical drawing in such a way as to meet the requirements of the

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country? Why, the total payments on results for the 23 branches of scientific instruction under the patronage of this department is L.5000, about one-seventh of the sum spent in encouraging free-hand drawing! About 7000 students learn these 23 branches of science, as compared with 105,000 learning the elements of free-hand drawing. The department has not yet, I think, earned the right to sit down complacently satisfied that the requirements of the country are met.

But you may fairly ask me, how it is possible, if mechanical drawing be really so important to us as a manufacturing nation, that it is so little taught? Does not the number of art students prove that there is a demand for artistic training, and the small number of mechanical schools shows that there is no demand for the scientific branch? The answers to these questions are, I think, simple. Our countrymen have so great a natural aptitude for all matters connected with mechanics, that all who need this special knowledge do, by hard labour under sheer necessity, acquire it. Only those plants and trees which are not indigenous to the soil require costly apparatus and careful watching. Art is not indigenous here, but science is, and, above all, the science of mechanics; therefore, while under the fostering care of governments and academies, our fine art languishes, though pampered with wealth, mechanical arts flourish wherever two or three men in fustian combine to work together. But what should we think of the farmer who neglected the produce for which his soil was fit in favour of exotic plants, which could only be coaxed into feeble life with infinite care and ruinous expenditure?

Another reason for the neglect of mechanical drawing in favour of free-hand drawing is to be found in the dilettante interest which the more cultivated classes take in art. The patrons of schools, squires, clergymen and their families, can sketch a little, or at least know what a free-hand drawing looks like, while they are generally utterly ignorant of the meaning of a cross section or an elevation. But when the schools and classes are initiated by workmen, then we see a class of mechanical drawing invariably instituted as

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of the first necessity; and if any one will question workmen and foremen as to their desire for a knowledge of artistic drawing as compared with mechanical drawing, they will soon cease to doubt the existence of a real demand, although in all Scotland there were only 61 persons in 1866 who received this kind of instruction through schools assisted by government through Captain Donnelly's department.

I hope you are convinced of the importance of this branch of elementary scientific education, and will now proceed to discuss remedies which ought at once to be adopted.

It is quite insufficient to pay teachers on results, for the following reasons:—

1*st.* The persons really competent to teach mechanical drawing cannot be professional teachers, but must be practical draughtsmen. The knowledge which the workman wants cannot be given him at a school where the master teaches reading, writing, arithmetic, geography, and has just managed to get a certificate that he understands geometrical projection. The knowledge the workman wants is the knowledge acquired by the draughtsman from long familiarity with practical constructions. To this man plans, cross sections, and elevations of machinery are all as real and as natural as the things themselves. He does not look upon them as results of geometrical propositions—he generally does not know the meaning of an orthogonal projection, and is wholly ignorant of the scientific part of descriptive geometry; but he is familiar with the methods of representing the most complete structures in such a way that the most accomplished mathematician shall have no fault to find with his work, while it will be intelligible to the workman of average experience. These draughtsmen cannot be had in parish schools, and to offer those in towns a few shillings a head for such of their students as may pass an examination is a farce. These small payments are of great use to the professional teacher, whose business it is to teach, and who can send up men for examination in many classes, but payment by results will hardly ever induce draughtsmen to form classes. Then, for mechanical draughting, a large space is required for each pupil, a good light,

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at least two hours continuous work at each lesson, a collection of somewhat expensive drawings and much more expensive models, and all these things cannot be paid for out of the L.340 allotted to this branch of science in Great Britain, nor out of any increased sum earned on the same plan. Lastly, the instruments used are expensive, and such as young mechanics can rarely afford to buy. On all these grounds, which distinguish this branch from most of the other branches of mechanical science, it must be separated from these, and encouraged on a wholly different plan.

I therefore propose that every government school of art or design, of which there are about 100, *should be required to open classes of mechanical drawing, and that these classes should be taught by professional draughtsmen*—who should receive a salary such as would make it well worth while for the leading men in each town to compete for the appointment—in addition, the teacher should receive a portion of the fees paid by all classes of students, for I am no believer in gratuitous instruction.

Some classes are even now open for this branch of drawing, and the students in these do not seem to be counted in Captain Donnelly's Report, nor do I find any special mention of them in the general report of the department. I will refrain from criticising the work done in these classes, taught by men who are really good masters of artistic drawing, and who might, perhaps, teach elementary geometrical projection, having obtained certificates of competency in this respect, but they are not professional mechanical draughtsmen, and cannot teach things with which they are unacquainted. The contrast between the artistic work done in our schools of design, and the mechanical work, is as glaring as the discrepancy between the L.340 and L.35,000 paid for the encouragement of the two branches.

Instead of the one little heterogeneous class taught by a certificated teacher, there should be in each school four distinct departments—one for mechanical drawing proper, one for the drawing of buildings, one for plans and surveys, and one for geometrical projection. In each department there should be an elementary and an advanced class, and each

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class should be taught by men acquainted with the special work.

There should be prizes given upon the plan adopted for artistic drawing, and these prizes should be equal in importance to those given for excellence in the fine arts.

In each school there would therefore be prizes—

1*st*, For highly-finished shaded and coloured drawings.

2*d*, For linear drawings, neither coloured nor shaded.

3*d*, For large scale detail drawings, boldly coloured in the style required for use in the machine shop or in the field.

4*th*, For plans and surveys.

5*th*, For drawings of the constructive details of buildings.

6*th*, For writing and printing.

7*th*, For geometrical projections.

In the larger schools I would add prizes for perspective drawings, accurately corresponding to given plans and elevations.

There should be an annual exhibition of the work executed by the students, and there should be a national exhibition of the prize drawings and national prizes for the whole of Great Britain. This would be encouragement on a very different scale from the prizes now offered for little linear drawings, five of which are to be executed in four hours, and which test the power of the draughtsman to enlarge little lithographed sketches. I am convinced that every one of the above classes would fill in every considerable town; but if, instead of teaching the practical work, geometrical projection and the French form of descriptive geometry be taught, hardly a student will be found.

Another objection may be, that mechanical draughting ought to be taught in connection with scientific establishments rather than through schools of art, inasmuch as it is more closely related to mechanics and mathematics than to anything æsthetic. My answer is, that the arrangements in schools for fine arts are adapted for drawing both as to space and light; that government establishments for the fine arts exist already all over the country, to which the new classes can be affiliated, whereas the schools of science do not exist; and lastly, that the scientific part of mechanical

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drawing is wonderfully small. There are excellent draughtsmen who are wholly ignorant of Euclid and guiltless of algebra. The very fact that our workmen do come to understand the drawings of the work they have to execute is a proof that no scientific training is required to render these intelligible. I have known a smith who, taught in a mechanics' institute by a locomotive draughtsman, learned in a very little while to make an admirable set of drawings of the smith's shop in which he worked, with the building, roof, forges, blowing-machinery, &c., in full detail. I have seen a whole class of lads of thirteen and fourteen executing excellent mechanical drawings—so good that I could have afforded to pay them to work in my office; and I am therefore certain that no considerable scientific training is required to enable lads and men thoroughly to understand mechanical drawing, and to represent accurately any ordinary structure. So far am I from thinking that it requires previous scientific training, that I believe mechanical drawing to be the one form of elementary science which practically can be taught in all schools. If we had in our government schools of art such classes as I have suggested, we should soon find that native draughtsmen would replace the French, Germans, and Swiss, who, to our shame, now fill our drawing offices.

I will now for a time take leave of the Science and Art Department, and consider what should be done in primary schools to carry out the second resolution of the Conference, that elementary science should be taught in all schools. I often see proposals that drawing should be taught in all the primary schools of the country, and the proposition is supported by the argument, that drawing educates the faculties of observation. If this be true to some extent of ordinary perspective drawing, how much more is it true of what I call mechanical drawing? The greater or less accuracy of a perspective sketch of any object is a matter of appreciation. The accuracy of a plan, elevation, and section, are matters of certainty. I hold that a child who has acquired the power of measuring the simplest forms, and representing these by a plan and elevations on which the dimensions

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can be written, has acquired a faculty which will be of use to him in every calling of life, and will have had mental powers awakened which no mere copying would ever awaken, and which will lie dormant even if he learn to represent actual objects by freehand drawing, a degree of proficiency which cannot be hoped for in primary schools.

It may seem to many that the plans and elevations of natural objects are more difficult of execution than the perspective sketch. This I wholly deny, in Great Britain at least. A child of seven or eight years old can be taught to understand and make the plan of a room, to measure the dimensions, and write them correctly on the plan. The very fact that children understand maps shows the readiness with which the mind receives this simple geometrical conception.

A plan and elevations of any object are only the maps of the top and two sides. The apparatus absolutely necessary to teach the elements of this branch of drawing, is a small collection of simple geometrical wooden models. The figured hand sketch of these on a slate would be all that would be expected from the youngest or poorest scholars; add to this some paper scales and set squares for the older boys, and the parish school would be completely equipped with all that is necessary for the elements of this branch of education—except the teacher. This, then, is the elementary science which, in accordance with the resolution of the Conference of this Society, might, I think, be introduced into every school. When elementary science is mentioned, some think of botany, physiology, the laws of health, political economy, geology, mineralogy, astronomy, and so forth. I hold the unpopular opinion that not one of these things should be taught in any primary school. The sciences may be divided into two classes,—the mother, or fundamental sciences, and the derived sciences. Mathematics, physics, and chemistry as a branch of physics, may be called the mother or fundamental sciences. Without a knowledge of these it is useless to attack the derived sciences, except in the most superficial manner as mere sciences of classification. Mathematics and physics, including chemistry, should therefore be the basis of a scientific education, as Latin and

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Greek have formed the basis of a literary education. Again, the simpler branches of mathematics must precede the study of chemistry or the other branches of physics. Arithmetic is the first branch of mathematics; and the representation by plan, section, and elevation of simple structures may conveniently form the second branch of applied mathematics. What algebra is to arithmetic, geometry is to mechanical drawing, and it is not only possible to give a fair knowledge of practical arithmetic and drawing in primary schools without algebra or geometry, but it is the only way in which we can hope to give that knowledge. Physics and chemistry require comparatively costly apparatus and highly trained teachers; very little that is worth knowing could possibly be learnt in any primary school on these subjects, and unpopular as the opinion is, I would not make the attempt. Much that will interest the intelligent and awaken new ideas, may be learnt in after life from lectures such as are now being delivered in connection with our admirable museum. I heartily hope that similar lectures will be given in all large towns, but they will rather be a healthy form of intellectual recreation than a means of giving scientific education; and in our primary schools for the working classes I see only one possible branch of science open for our adoption, namely, the scientific representation of mechanical and other simple structures. In making the attempt, we shall start with the support of the whole artisan class, which would be delighted to see its children acquiring precisely those elements of knowledge which as skilled workmen they will have to apply; and we shall start with a strong national bias or talent for the work, whereas in the cultivation of artistic representation the work is impeded by frequent natural incapacity.

The second suggestion which I have, therefore, to press upon your attention is, *that the form of elementary science which is best adapted for introduction into primary schools, is the representation of bodies of simple form by plans, sections, and elevations drawn to scale, or with figured dimensions.* To carry out these views in England, it would be necessary that the Committee of Council on Education should add

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clauses to the Revised Code, under which they should, out of the annual grant made by Parliament, undertake to aid inspected schools giving instruction in elementary mechanical drawing, by annual capitation grants conditional on the attainment of a certain standard of proficiency as attested by the inspector; in other words, this first and most elementary branch of science should be put on the same footing as reading, writing, and arithmetic. It would also be necessary that the teachers trained in normal schools should be required to take up this special study. By these simple regulations the new study would gradually but surely be introduced throughout the primary schools of the country.

I regret that I am not yet sufficiently familiar with the machinery by which the primary schools in Scotland are managed, to be able to make any practical suggestion as to how and where the experiment should here be first tried, but one application will suggest itself to all our minds—I allude to the great charitable hospitals with which Edinburgh is surrounded. Some, at least, of these are devoted to the education of artisans, and all are intended for the instruction of the productive classes—the classes which use machinery if they do not make it. I believe there is no attempt to teach mechanical drawing in any one of these, and I assert that it should be taught in all.

But when a suggestion of this kind is made, it is continually met with the question, How are we to find time? the boys are already fully occupied, and what can we give up? As an answer to this, I will read what was the programme of a well-managed Edinburgh hospital and that of a Prussian industrial school.

Scotland.—Latin, French, English, writing, drawing, singing, dancing, drilling.

Prussia—1st Course.—Mathematics, chemistry, physics, German, arithmetic, drawing, architectural drawing, machine drawing, modelling.

The Latin, French, dancing, singing, and drilling, have disappeared, none but the mother or fundamental sciences are taught, and the three forms of drawing have one-third

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of the whole school time allotted to them. Architectural drawing is no doubt a misnomer; by this is meant the drawing of ordinary buildings.

In the higher course lessons are added in the knowledge of machinery and in mechanics,—two very different things,—in chemical technology, physical technology, the construction of buildings, the knowledge of materials, and chemical analogy; but drawing has still one-third of the whole school time given to it.

In the Edinburgh hospital only the least useful form of drawing was taught, it got two hours a-week, and all the inspector could say of it was, that the course was well adapted to develop any power in this direction which a boy might possess.

Can any Englishman doubt which of these two courses of study is best adapted to train either foremen or manufacturers? who does not know that the little Latin will vanish without leaving even a tincture of literary training? that the French will never be learned in any form which can be practically used, and will never be required by nineteen out of twenty pupils. What foreman has any need of French? Who really thinks that dancing and singing are to be compared in value with any one of the subjects in the Prussian course? Why, then, do not our great industrial schools boldly throw off these traditional bonds, and follow the well-tried course of the German schools? At one time Latin was the one thing which could be accurately taught, and was therefore the one means of mental culture. Long after this ceased to be true it remained a necessary passport to a rise in social position; but except for the church, who now can suppose that a knowledge of Latin is likely to aid an ambitious youth to rise in life as a knowledge of physics and chemistry would aid him?

I am the last man to decry literary cultivation, but Latin, as taught in middle-class schools, gives no literary culture; French gives still less; and I call, therefore, on all interested in middle-class education to give literary culture through the mother tongue, and mental culture through natural science, which would be learned with an avidity only to be

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equalled by the distaste with which scraps of dead Latin and imperfect French are rejected by a lad who knows that not a grown man of his class retains any knowledge of either, or cares to acquire it.

Let me not be mistaken. For the highest class of education I look on the dead and foreign languages as essential, but they are useless unless pursued until the student has them well under command, and can forget the instrument through which he communes with the thoughts of men of other nations, and of all ages. I am no fanatic, who would destroy a great instrument of culture by which many generations have been trained; but I say, that for workmen, foremen, and the smaller class of manufacturers and tradesmen, such mental provender as is afforded by a little Latin, French, music, dancing, and drilling, is garbage as compared with the healthy food in the Prussian school.

I will now draw your attention to what can be done in a charitable institution in Paris, worthy of imitation in many respects, although managed by a Catholic religious body called the Frères Chretiens, who are by no means universally popular. I allude to what is called the school of St Nicolas in the Rue Vaugirard. This is a boarding-school for the poorer classes, administered and taught by the religious body, the members of which live in the school, and receive their food, and about L.10 annually out of the profits of the school. About 1700 workmen's sons are boarded and clothed in this establishment, and they pay L.1, 4s. per month during ten months in the year; the school is slightly assisted by charitable bequests, and the average cost of each pupil is L.17 per annum, the total revenue being L.28,000. The boys are received between the ages of seven and ten, and some do not leave till about eighteen or nineteen. The mechanical drawing executed by boys of thirteen or fourteen in this school is wonderfully good. There were plans of the kitchens to a large scale, showing the details of the cooking apparatus, steam-boiler, and so forth, executed from dimensions taken by the pupils themselves. I saw the drawings in all stages of progress, and each drawing differing in colour and arrangement according to the disposition of the

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draughtsman, showing that the work was really that of the pupil, and not merely a dead transcript from the teachers' work.

The average cost of a pupil in a Scottish hospital is L.41, 10s. per annum. Exclusive of bursaries, each pupil in Donaldson's Hospital costs L.24, 15s. per annum. The cost of each pupil in the French establishment being only L.17, may be considered wonderfully small; perhaps the economy will be best understood when I remark, that the Scottish hospitals, for L.44,000, educate, board, and clothe 1064 scholars, while the French school, for L.28,000, boards, clothes, and educates 1700 boys and youths. The dormitories and arrangements for cooking appear excellent, and the youths contrast very favourably in appearance with the pupils in the great French Lycées. The French establishment is also remarkable for a curious and excellent device by which the Frères Chrétiens teach their pupils trades while retaining them within their walls. The plan is devised with the object of retaining moral control over the youths up to a late period in life, and is probably not worthy of imitation in our hospitals, since I believe that a youth of ordinary morality is better fitted to do his duty by mixing in the world than by semi-monastic training; the plan might, however, perhaps be applied to our industrial and reformatory schools. I will, therefore, so far digress as to sketch the system.

The school provides a series of workshops, fitted for the production of numerous articles made by various trades in the town. Thus, in Paris there are workshops for mathematical instruments, levels, lenses, musical instruments, bronze statuettes, packing-boxes, the design of shawls, &c. The school then allows a manufacturer, say of optical instruments, to use one of these workshops with the tools it contains. The manufacturer employs as apprentices, or rather as workmen, as many pupils of the school as the workshop will accommodate, introducing one skilled workman into the shop to teach and direct the lads, who remain for four years as apprentices, receiving nothing for their labour. The master makes a profit by these apprentices, but is bound to accept any lad the authorities choose to give

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him. The school receives each year from the apprentice the monthly payment of L.1, 4s., and continues to board and clothe him. The apprentice works nine hours per diem in the shop, has classes in the evening, and learns to make exactly the articles required in the trade, so that on leaving the workshop he is able to command the full wages of a workman, and, indeed, in some departments, as in shawl-designing, a pupil in the fourth year may be worth L.70 or L.80 to the master. I saw 140 apprentices thus occupied, and there is no doubt that the plan is thoroughly successful. It might be applied to reformatories, so as to give lads a real trade education, and interest them by allowing them to make things which they know are of real use; but my chief object in drawing your attention to the École St Nicolas was neither to insist on its economy, nor its successful industrial education, but to the admirable mechanical drawing which is executed by lads at a very early age. I fear that I must have wearied you by ringing continual changes on those two words, and I will endeavour to justify the high value which I have attached to this branch of elementary education by quoting the following passage from the report of the French Commission on Technical Education:—

"*Drawing, with all its applications to the different industrial arts, should be considered as the principal means to be employed in technical education.*"

Granting the great importance of drawing, you may fairly ask me what analogous proposals I have to make as to mathematics, mechanics, chemistry, and physics? I may remind you that I have already expressed the opinion that these great studies will not be successfully prosecuted without a great reform in all our middle-class schools, effected by parliamentary legislation of a very difficult nature. I fear the elementary schools, inspected and aided by the Council on Education, can do nothing to forward these studies, except by improving the foundation on which they ought to be built; and I am certain that the grants administered by the Science and Art Department can do very little to meet the requirements of the country

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as to these great studies. Indeed, I am not prepared to hand over the scientific training of the country to that department. The subject of the introduction of public graded schools, with classical and scientific courses fit for this great country, is too vast a subject to be treated of as part of an address. I am not propounding a complete scheme for the scientific regeneration of the country, but only endeavouring to make some practical suggestions, which might be carried into effect without extensive parliamentary legislation, and, omitting any reference to what may be called the secondary schools, I will now make some remarks on professional and scientific education of the higher grades.

I am opposed to the creation of special colleges for the education of special professions. In my introductory lecture delivered at the University, I explained at some length my reasons for preferring that our universities should be developed so as to train men for the new learned professions. It is said, and said truly, that the universities will never be able to train men so fully for any one profession as a special school would, and this with me is a reason for preferring the university. A special college will attempt to teach a man to be an engineer, and I hold that it will necessarily fail in doing this, for that practice is the only training which can ever give a man that knowledge which is essential before he can be called an engineer. I apprehend that what is true of engineering, civil and mechanical, is also true of the cognate professions of architecture, building, and of the management of large factories. These things cannot really be taught in classes; and a personal inspection of the very excellent special colleges abroad only convinced me that they were (so far as a great portion of professional training is concerned) merely passable makeshifts, replacing the English plan of apprenticeship by an inferior system.

But while the business or profession can only be taught by practice, the preparation for that practice can and ought to be given in schools. This preparation is admirably given in the foreign colleges, but here again the special college labours under a special disadvantage. The preparation for the learned professions should consist in the acquirement of the

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fundamental sciences of mathematics, chemistry, and physics, with some derived or secondary sciences, such as mechanics, geology, &c. Now all these things are already taught at universities, and the universities command the very best men as professors. It is better that all the architects, engineers, and manufacturers should learn their mathematics, chemistry, and physics from one man in one class room, for they will then learn from the very best man who can be found; and, abroad, those special colleges are the best which act on this principle, becoming really universities in all but the name. Another disadvantage of the special school is, that they are led to carry this preparatory training much too far. A glaring instance of this is to be found in the Polytechnic School in Paris, where every government engineer receives a mathematical training such as would fit him to be a wrangler at Cambridge, and very generally unfits him to be an engineer. Moreover, I desire for every engineering student a liberal education. It is probable that wide differences of opinion would be found among us if we were called upon to define a truly liberal education; and the liberal education of to-day will not be the liberal education of to-morrow. But we may all agree that the general course of education given in a university, where men of all professions and every turn of mind mix together, is more likely to be liberal and wide in its scope than the education given in a college devoted to any one profession, be that profession law, physic, or divinity itself. I am quite aware that, as subordinates, comparatively uneducated men are often as useful and trustworthy as their more showy competitors; but in the higher walks of the profession, a good general education is of great use in dealing with all forms of business, and it is of incomparable value to its possessor, by directing his intellect and his tastes to the purest and noblest food.

I hope, therefore, that our professional men will continue to pass through our universities. But in order that this may be the case, the universities must be developed, so as to meet the requirements of old professions as they extend, and new professions as they arise.

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Dr Lyon Playfair drew my attention to the fact that existing universities almost all arose as professional schools of law, medicine, and divinity, for a long time the only learned professions. Now that there are new learned professions (I may surely claim that title for engineering at least), the universities should recognise the fact, and provide the necessary curriculum, and the necessary degree or attestation that this curriculum has been profitably followed. We boast in Great Britain that our institutions grow; whereas foreign institutions are too often shackled by such bonds, that, unable to develop, they grow old and die. This fate has actually befallen the scientific faculty of the University of Paris. The class-rooms are deserted, the professorships are despised sinecures, and the whole scientific training of France is given in the new special schools, such as the Polytechnic School and École Centrale. I hope we may never see our ancient universities wither in like manner; but to avoid a similar fate, they must avoid similar conduct.

Edinburgh at least has incurred no reproach as yet. The foundation of the chair which I have the honour to fill is a proof of the munificence of the patrons of its University. The reception I have met with proves, not my merit, but the interest with which this new development is regarded in the city; and therefore I am emboldened to urge those measures upon you which I think the University should be encouraged to adopt.

The system of pupilage for an engineer must be maintained, and pupilage should begin at the age of eighteen or nineteen. The student has, therefore, no time to acquire the higher mathematics, or to follow any large number of courses on special engineering subjects. If our young engineers could enter the offices and workshops as pupils possessing a competent knowledge of geometry, the elements of algebra, trigonometry, physics, chemistry, mechanics, and drawing, they would be able during their pupilage to make a really good use of their time, instead of, as at present, too often employing these years in learning, in a very rude way, projection, mensuration, tracing, and such other

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elementary branches as they should have mastered before entering the office.

For engineers, at least, no other courses of lectures are required than are now open. What is really necessary is, that parents and intending students should be induced to take advantage of the facilities which already exist. No pass or competitive examination bars the entrance to our profession, and a good fee and some personal knowledge of the candidate are the inducements which lead engineers, in the south at least, to accept pupils. Now I cannot urge too strongly on the profession that the improvement of the education of the younger members lies in their hands. If they will require a real preparation from their pupils, if they will show a real preference to the well-prepared pupil, the cause of scientific education will be won. How can they practically show this preference? So long as there is no recognised curriculum leading to no recognised examination, they can at most ask if the candidate has attended certain classes, such as my own, and with what success. The profession cannot institute a sort of matriculation examination, and a mere general inquiry as to previous training will lead in future to no better results than hitherto; but if the University institutes a recognised examination, conferring a recognised degree or diploma, the profession can then select their pupils by asking a perfectly definite question, Has he or has he not passed this degree? and if so, with what credit? This is one reason why I think it is incumbent on all universities professing to prepare engineers that they should institute definite engineering degrees. The particular examination which should be employed to test the fitness of a pupil to enter an engineer's office or workshop should embrace only the elements of those subjects which I have named above; but these would ensure that the pupils in engineers' offices who had passed that examination should be very differently prepared from the pupils with which I have come in contact (in the south).

I call, therefore, on my professional brethren to select their pupils with reference to their previous training, and I call upon the University to organise such a curriculum, and to

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institute such an examination as will enable pupils to be thus selected.

In course of time, should the engineering instruction prove successful, it will be necessary to institute some new chairs, such as that of architecture, and possibly to divide engineering into two branches, with lectureships on special subjects; but every step should be justified by the success of each previous advance.

The University can, however, at once do more than simply test the fit preparation of engineering pupils by the institution of a degree corresponding to that of Bachelor of Arts. It might also offer to test how far, at the end of his pupilage, each pupil has benefited by his practical training, and then give a real diploma attesting his capacity in the particular branch which he has studied. This was the proposal contained in the University Calendar, but abandoned for the present, owing to legal informalities attending its adoption.

Some disapprobation has been expressed at the proposal to institute new degrees, and the opposition has come from men of different classes—for instance, from Conservatives, who object to new degrees because they are new, and who fear a degradation of academical distinctions. To these opponents I would point out that engineers now form a real new learned profession, as much entitled to academical recognition as the older professions were when the old degrees were instituted. To institute new degrees in the old universities is to carry on the old traditions unbroken; and if this be not done, then the new professions will create schools and distinctions of their own, and the old institutions will fall as old trees fall when their growth is ended. The strictest watch should, however, be kept, to ensure that the new degrees are, if anything, harder to attain than the old ones.

The second class of opponents are those who say that no examinations can test the proficiency of a professional man. I have very little doubt that this was the feeling of some of the older medical men when degrees in medicine were first instituted; but if engineers could only be examined after

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the fashion of some recent examinations the papers of which I have read, I should cordially agree with the opponents of the measure I now support.

As an illustration of my meaning, I will take the liberty of criticising one point in the examination which is to be held for the Whitworth scholarships, under the management of the Science and Art Department. This examination might be expected to correspond with that which all should take before entering an engineer's office or workshop. Its object is to select those youths who, by two or three years of additional study, are likely to become useful engineers. Consequently, we find a list of subjects closely agreeing with that which I proposed for our University examination; and among these subjects is "Applied Mechanics." The French and Professor Rankine mean by Applied Mechanics the application of the purely theoretical mechanics to the problems which occur when dealing with material bodies. Thus Professor Rankine's book on Applied Mechanics treats of the principles of statics, the theory of structures, the strength of materials, kinematics, the theory of mechanism, and the principles of dynamics—all things which the pupil entering on practical work should know. But the examiner of the Science and Art Department has understood Applied Mechanics to mean a knowledge of machinery—a knowledge which no man can acquire except by long practice, and which a pupil entering a workshop can by no means have acquired; indeed, no man in his whole lifetime ever acquires it thoroughly except in certain branches of machinery.

One question asked is—

15. In the older vertical saw frames a ratchet wheel was employed to urge the timber forward for the cut; in modern frames a similar arrangement is employed, but with this difference, that the teeth of the ratchet wheel are dispensed with, and a frictional grip, adjustable to any rate of feed motion, is substituted. Make a pen and ink sketch of any such contrivance by which the object can be effected?

Another is as follows:—

16. Lathes for boring guns are now being constructed, in which the power is to be accumulated by worm gear instead of

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> spur or bevel gear. The accumulation of power is 150 to 1; a worm wheel is fixed on the main spindle, and the worm works in oil. Make a sketch of the head stock only, showing the driving pulleys and the gear.

Now, unless a man be told beforehand, you will be examined in sawing machinery, and in machinery for the manufacture of ordnance, I hold that his knowledge or state of preparation cannot be tested by questions like these. If I am to be at liberty to pick any details from any class of machinery, and ask men to make a sketch of it, the merest accident will determine who would give me the best answer. Probably, if I were to ask the examiner to sketch the form of break employed in retarding submarine cables during submersion, and describe its principles, he would be as much puzzled as I should be to sketch a detail in gun-boring machinery. The questions require no particular knowledge of the principles of mechanics, but an absolutely unlimited knowledge of the details of machinery; and to my mind it is absurd to ask from pupils about to enter on a course of practical study any but the most elementary knowledge of the elementary parts of machines.

This, then, I take to be an example of an examination, devised by a very competent engineer, who has not sufficiently considered what examinations can be expected to do. He might defend his paper by observing that the science and art examinations were meant to test the proficiency of teachers, and for this purpose the examination is only faulty in requiring superhuman knowledge. I sincerely hope that no similar paper will be put before young students.

On the other hand, neither in theoretical nor in Applied Mechanics is there a single problem as to the strength of materials and the stability of structures, the proportions of which ought to exist between firebar surface, heating surface, the dimensions of cylinders, &c. in steam engines. Nothing is said of the geometrical methods which engineers find so convenient for solving the problems of strains on framework, nor are there any questions testing the capacity of the student to understand the graphic representation of results by diagrams; whereas I hold that to those points the student's

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attention should be directed before he enters the workshop, and that he cannot possibly be expected to make a pen-and-ink sketch of a ten-ton hydraulic crane, of a steam hammer, of a turbine in equilibrium adapted to secure the best results from a fall of sixteen feet, or even of a hydraulic accumulator.

I wholly disbelieve in any attempt to ascertain a man's mechanical knowledge by shutting him up for four or five hours without any books of reference, and asking him to answer eight such questions as these, ranging over every variety of machine. The best men in the country could not pass such an examination; and a man who, in after life, attempted to design machines of which he had only a general knowledge, without referring to all the drawings he could find of similar contrivances, and without giving the subject a day or two's consideration, would be an exceedingly bad engineer.

Then, you may ask, to what kind of examination would you subject your candidate for an engineering degree? First, I would subject him to an examination in some one or two branches of theoretical knowledge, allowing him to choose the branch, but then making the examination one which would entitle the successful candidate to honours in that branch. Next, in the practice of his profession, I would also allow the candidate to choose his department. Thus, he might elect to be examined in railway machinery, or in marine engineering, or in tools, or in telegraphy. Then I would set him a real piece of work to do, giving him perhaps a month or two months to complete the work. At the end of that time he would bring up his designs, calculations, estimates, precisely as if I were his chief engineer and he were a resident or head draughtsman. He should have free reference to all books and persons whatever; but when the designs were laid on the table he should be subjected to a searching cross-examination as to his reasons for adopting the given dimensions, materials, and forms; he should be called upon to justify his estimates and explain the motives which guided him in drawing each clause of his specification; and I venture to say that a man who passed such an

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examination as this, before a board composed in part of professors and partly of practical engineers specially acquainted with the branch of engineering in question, would prove a really competent engineer in that branch; and I also think that there are hundreds of men in England who would be willing to purchase a diploma by undergoing such a real test as this, who would laugh at cramming themselves with undigested pen-and-ink sketches for a three hours' examination in machinery at large.

I have drawn no fancy sketch. The examination I recommend is simply the form of examination actually held in Germany with great success. It is usually taken by men who have been some years in practice, and is, I believe, a sure passport to advancement.

A degree given in this way would be a degree worth having in England also; nay, it would be especially valuable to the young engineer, who at present has no way of gaining any distinction except in the very limited circle of the shop or office in which he works. The public credit due to all works goes to the chief engineer or the responsible manager of the firm; nor is this essentially unjust, though young men sometimes rebel at it. The responsible man must reap the shame or glory, but owing to this very fact young engineers would be peculiarly glad of an opportunity of gaining real distinction.

Another motive for giving degrees in engineering is, that the want of such an official diploma subjects Englishmen abroad to a serious disadvantage. The French or German candidate for work pulls out his official diploma for inspection, while our Englishman has nothing to show but an informal note from somebody saying he is an excellent man in a general way. What wonder if the duly accredited engineer be preferred, so that we find the French and Germans boasting that foreign powers now always send to them for engineers, and no longer to England? I believe this is a fact, and that the absence of degrees to a great extent explains it. I hope, therefore, that this Society will give its hearty support to the institution of these new and much-wanted academical distinctions.

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I will now very briefly review the several recommendations which I have ventured to make.

After approving the report of the Schools Inquiry Commission, by which real public schools of all grades would be established throughout Great Britain, I drew especial attention to mechanical drawing as the branch of elementary scientific education which I thought most important to our workmen and foremen; I suggested that the government schools of fine art should be extended so as in all cases to include a series of classes for instruction in all the branches of draughtsmanship; I recommended that these classes should be taught by practical draughtsmen, not by men whose profession it was to teach; that prizes should be offered for each branch of drawing, with national exhibitions and national prizes; and, that the more costly and permanent articles required in the class should be provided for the student.

I further suggested that this branch of elementary scientific knowledge is peculiarly well adapted for introduction into primary schools, because it stimulates accurate observation, giving a boy the means of expressing his ideas accurately, and of acquiring information from books and periodicals, and because it is suited to the genius of this country; I endeavoured to show that this important step could be made at once, by putting this kind of drawing on a par with reading, writing, and arithmetic, in the payment for results.

Passing to the higher professional training, I deprecated the establishment of special colleges, but, on the one hand, called upon the universities to institute new chairs and new degrees, to meet the requirements of new professions; and, on the other hand, I called on these professions to support the universities, by according a real preference to the men who were well prepared over those who declined to take advantage of the facilities given them.

I have now the great pleasure of informing you that I have to-day received a proof of the preference for educated pupils felt by one of the leading firms of mechanical engineers in Edinburgh. I cannot better explain my mean-

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ing than by reading the following extract from minutes of a meeting of the directors of T. M. Tennant & Co., Limited, held on Tuesday, the 5th of January 1869 :—

"Mr R. W. Thomson moved, and it was unanimously agreed, that to encourage the new mechanical engineering class in the Edinburgh University, this Company will grant a free pupilage, once in three years, to the most meriterious student of the class."

This valuable endowment has, I think, been given in a form peculiarly well suited to stimulate the scientific education of our young engineers, by showing that the professional men consider that the road to practice should lie through the College gates.

On Photometry; with special reference to some Improvements on Ritchie's Paper Photometer: and on a proposed new branch of the subject, to be called "Analytic Photometry," which shall deal with the Chromatic Composition of Lights.
By Robert H. Bow, C.E., Edinburgh.*

The art of photometry, or the measuring of the intensities and illuminating powers of the rays of light, whether these be received directly from their source or by reflection from another body, may be conveniently divided into three branches, as follows :—

1*st*, That which has regard simply to the powers of ordinary illumination, or to render white objects visible to the human eye.

2*d*, That which estimates the penetrating power of a light—a quality required for lighthouses and signals; and,

3*d*, That which, viewing light as of a compound character, pays attention to its chromatic composition, and measures its richness in the rays that belong to different regions of the spectrum. This branch may be called "Analytic Photometry."

A fourth branch might have been added, taking account of the chemical or photographic powers of lights. This has

* Read before the Society on 27th March 1865, and awarded in 1869, the Society's Medal and Plate, value Five Sovereigns.

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received the name of "Actinometry," and it will be best to confine the domain of photometry proper to the visible rays of the spectrum.

FIRST BRANCH.—*Measurement of the Illuminating Power.*

[In discussing this branch, the author first points out the great misconceptions to which we are liable when we trust to the judgment of the eye alone as a photometer. He then gives an account of the photometers invented by Count Rumford and Professor Wheatstone, the polarising photometer of Babinet, Professor Ritchie's reflecting photometer, and Ritchie's paper-covered photometer; and expresses the opinion that for ordinary purposes, the question of preference lies between Bunsen's and an improved form of Ritchie's. He then proceeds as follows to give a description of these.]

Particulars of Professor Bunsen's photometer given by Dr Fyfe have already appeared in our Transactions (vol. iii. pp. 242–4), and this photometer has since then been very generally adopted by the gas companies.

The principle of this photometer essentially consists in comparing the brightness of a greased part of a piece of paper with the more opaque ungreased part, one light being placed before and the other behind the paper. The paper is usually prepared by saturating it with spermaceti, all except a round central spot of about an inch in diameter. It requires great care, however, to arrive at a satisfactory result. If a paper too thick or too thin be used, the prepared paper may appear equally brilliant when inspected on one side; but on looking at the other, the central spot may be too dark or too light. When in a satisfactory state, each surface must tell the same tale. The cause of this necessity for choosing a paper of a certain thickness and character is, I presume, as follows:—The greased portion does not owe all its illumination to the light behind it; some of that light will, indeed, be lost by absorption in passing through the substance of the paper; but it must reflect some light received from the source in front. The ungreased portion, on the other hand, besides reflecting the light in front, will also

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transmit some of that received from behind. The thickness of the paper affects all the elements in the question, and therefore becomes a means of regulating the effects. The point from which the paper is inspected will also have an influence upon the appearance; this direction of observation is fixed by causing the paper to be viewed by reflection from a mirror.

This photometer seems capable of affording very accurate determinations, but it evidently can only be trusted to in careful and experienced hands; and I doubt much if, even on the score of delicacy of determination, it is equal to an improved form of Ritchie's.

Professor Ritchie's photometer is generally described as consisting essentially of a wedge of 90° covered with white paper. The two faces of the wedge are lighted up by either light respectively; and the observer looks towards the sharp axis or small end of the wedge, and shifts the instrument or the lights until the two faces of the wedge appear equally bright. The ratio of the values of the lights is then ascertained by calculating the inverse ratio of the squares of their distances from the arris. This instrument was probably used by Bouguer in France previous to 1760. It is very efficient, even in its rudest form, and I believe, if somewhat improved upon, would constitute the best photometer for general purposes.

When the planes in Ritchie's photometer are covered with paper or constructed of cardboard, an inclination of 45° is almost the worst possible angle that could be chosen. All paper possesses more or less *gloss*, and if the inclination be such as to send some light by *regular* reflection to the eye from this gloss, this proves very detrimental, as it greatly affects the comparison of the brightness of the two planes, seen as these ought to be by the light reflected irregularly, or scattered.

In the further discussion of the subject, it becomes necessary, from the peculiar nature of the paper surface, to proceed with it under two heads. Under the first, the surface will be assumed to appear equally bright as seen from all directions, and to be bright in proportion to the cosine of

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the angle of incidence of the light. If the paper or cardboard be dipped into a creamy mixture of water and fine whiting, it will, on being dried, approximate pretty nearly to this theoretically dead white surface. Under the second head, the surface will be assumed to be composed of ordinary good paper or cardboard, which I find to obey some remarkable laws in its changes of apparent brightness.

1*st*, *When the Surfaces are of a truly Dead White Colour.*—Although under this supposition the angle of 45° could not be open to the objection above stated, yet a more acutely formed wedge would be preferable on several accounts. *First*, The surfaces to be compared would be brighter, which in many cases is an advantage, and can always be modified. *Second*, Any small errors in the direction of the lights, or the inclinations of the surfaces, will produce much smaller errors on the photometric results when the angle of the wedge is acute than when otherwise. Thus, if the angle of incidence of the light, or what is the same thing, if half the angle of the wedge, be taken in succession equal to 45°, 30°, and 15°, and we assume in each case a constructive error of 2°, then the resulting photometric errors would amount to percentages or 3·5, 2·0, and 0·9 respectively; so that, with a wedge of 30°, the error would be almost reduced to one-fourth of that at 90°.

It appears, then, that when the surfaces are of a dead white, the smaller the angle of the wedge the better.

2*d*, *When the Surfaces are of Paper or Cardboard.*—The following experiments will bring out the peculiarities of the illumination of such a surface, and show to what a degree a paper surface differs from a *dead* white one.

Take a piece of fine white cardboard with as little gloss as possible; fold this to an acute angle, say of about 40°. Place it, like the wedge in Ritchie's photometer, evenly between two lights, so that on observing it in a direction at right angles to the line joining the lights, the two planes will be equally seen, and will appear equally illuminated. Now preserving the light, the eye, and the small edge of the wedge all in the same position, turn the wedge round its edge as an axis; by so doing one of the faces will be

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presented more directly to its illuminating light, and less of it will be seen by the eye, and the other plane becomes more oblique to its light, and faces more round to the observer. Now, according to the ordinary law of illumination, the first plane should appear to become brighter, while the second plane should become darker; the contrary, however, takes place. Again, let the cardboard wedge be opened out until it assumes an angle of say 120°, and going through the same course with it, the results will be found, in so far as the general changes in brightness are concerned, to agree with the usual law. There is evidently some intermediate value of the angle of wedge at which no decided change in the relative brightnesses of the planes will result from a small amount of rotation, and such an angle would of course be very suitable for the photometer. The question is not, however, quite so simple as it appears at first sight; for on using a wedge with an angle of 60°, provided the cardboard be the same as I have used, or some other particular angle of the cardboard differ, it will be found that the retiring plane *first* becomes *darker* than the advancing one, but finishes by becoming the brighter. The following table, derived from experiments with planes overlapping and illumined by the same light, will serve to explain these apparent anomalies.

Table I. of Equal Brightnesses, the Direction of Observation being at Right Angles to the Incident Light.

When the incidences are at the following angles, the apparent brightnesses are equal,	5° and 48°
„ „ „ „	10° and 47°
„ „ „ „	15° and 46°
„ „ „ „	20° and 45°
„ „ „ „	25° and 43°
„ „ „ „	30° and 40°
And the brightness is a maximum when the incidence =	36°

At incidences ranging from 30° to 40° very little change of brightness is perceptible, but we may set down 36° as giving the maximum of illumination.

Although the plane at 36° is *decidedly* brighter than one

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at 5° or 48°, yet the difference cannot be great. It is evident that if the wedge of the photometer be covered with such a surface, and be made with an angle of 70° or 72°, it may be turned about through several degrees, without any marked change in the illuminations of its faces; and hence, as the *first* advantage of using such a wedge, we may state it as free from errors caused by moderate inaccuracies of workmanship, or in the placing of the lights; *second* advantage, freedom from light reflected by the glass; *third* advantage, position of maximum illumination.

The angle of maximum brightness will vary with different textures of paper. On the one hand, some very rough soft papers may cause it to go down to 20° or nearly; on the other, some highly finished papers may make it approach too near to the angle of ordinary reflection. These should be rejected. In the table where angles near 45° occur, the results are to some extent doubtful; in observing these the eye was placed above or below the plane of regular reflection.

The apparent anomalies noticed in the appearances of the wedges, when turned round, are explained by the following table, which is constructed from the foregoing one. The wedges are supposed to receive successive partial rotations of 5° or 10°, and the resulting relative brightnesses are taken from Table I. The plane which becomes at any stage the brighter is pointed out by the figures denoting the angle of incidence being given in a heavier type.

It will be observed that, in the case of the wedge of 60°, the retiring plane first becomes the darker, and finally the brighter.

Table II.

Angle of Wedge.	Incidence with Lights equal.	Angles of Incidence after First Movement.	Do. after Second Movement.	Do. after Third Movement.	Do. after Fourth Movement.
50°	25° and 25°	**30°** and 20°	**35°** and 15°	**40°** and 10°	**45°** and 5°
60	30 and 30	**35** and 25	**40** and 20	50 and **10**	55 and **5**
70	35 and 35	45 and **25**	55 and **15**	60 and **10**	65 and **5**

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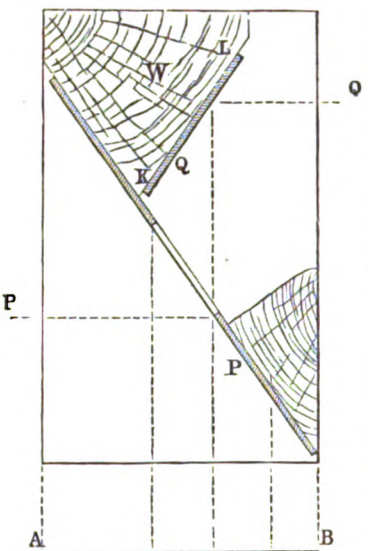
Having settled the best angle of incidence on the planes, it was next necessary to inquire if any improvement could be made in their arrangement.

The wedge, as arranged in Ritchie's photometer, has two other faults, in addition to that of the size of its angle.

Fig. 1.—Sectional Plan of Improved Ritchie Photometer.



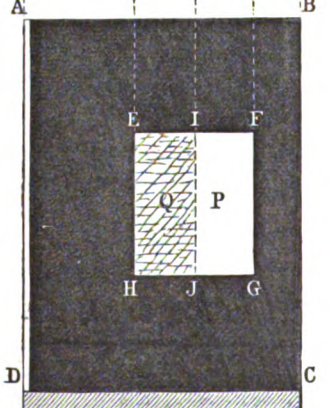


Fig. 2.—Elevation as seen when in use.

One of these is, that we do not compare at the arris the brightest sides of the two illuminated planes; the other, that the arris can never be made so perfect that when the illuminations are equal all indications of a division will disappear, which is one of the best tests of such equality.

But by adopting the construction shown in figs. 1 and 2, we get rid of these objections; and for the simple comparison of the illuminating powers of two lights, without regard to their colours, I have found this the most satisfactory arrangement, and capable of giving minutely accurate results.

ABCD represents a piece of stout white cardboard, with an opening, EIJH. The edge IJ must be very carefully cut, so as to leave no irregularity. This is best done by laying the card, face downwards, upon a sheet of glass. The whole of this cardboard is to be blackened, except the space IFGJ. Another piece of the same sheet of cardboard is to be fixed against the wedge of wood W, at KL, large enough to

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fill up the field of vision through the opening EIJH. The fibre of the cardboard in each case should be similarly placed in relation to the light falling upon it.

When the photometer is not used in a blackened room prepared for the purpose, it should be enclosed in a suitable box, open at each end, and with an aperture in one side, through which the illuminated planes, EJ and IG, may be inspected.

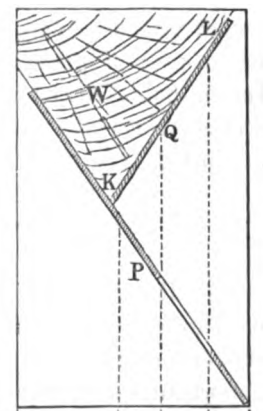
The photometer may be made of double the dimensions shown in the figures; but where portability is desired, the size may be considerably reduced without much inconvenience.

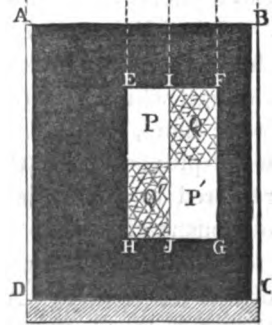
When the object is to detect differences in the colours of the lights, the following from of photometer is to be used:—

In the cardboard ABCD, two apertures are cut, represented by Q and Q′, and the whole coloured black, except the parts P and P′. Through the apertures Q and Q′ the second piece of cardboard, KL, is seen.

In using this photometer, the eye is made to travel up and down upon the line IJ, so as to compare alternately the upper and lower pairs of illuminated planes, when any difference in the colours of the lights will be rendered remarkably obvious. The explanation of this is of a physiological character, but very simple. When the eye dwells for a while upon a bright colour, it looses in some degree its sensibility to that particular colour, and virtually gains sensibility to the complementary colour. Thus, when the eye is observing, by means of the first form of Ritchie's photometer, we may assume that

Figs. 3.—Plan.





Figs. 4.—Elevation.

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the plane P is lighted by a candle or orange-coloured light, while the plane Q is illumined by gas or daylight, which by contrast is a blue light; now, as the eye dwells upon the pair of planes, watching the varying shades as the distances from the points of illumination are changed, the colour presented to either half of the retina remains unchanged. Hence each half gradually looses in a degree sensibility to the distinguishing tint, and each colour virtually becomes more grey in character, and the two planes appear less contrasted in colour than at first. But in the case of this second or compound form the opposite effect is produced. The eye rests for an instant on the upper planes P and Q, respectively blue and orange, and by so doing each half of the retina becomes virtually more sensitive to the tints presented by the lower pair of planes, so that when the eye is lowered to these, their contrast of colour comes out at first most vividly; and after a while, a similar result follows on raising the eye again to the upper pair.

Second Branch.—*The Measurement of the Penetrating Power of Light.*

I shall say little of these photometers, as they were quite new to me less than three weeks back, when Mr Thomas Stevenson called my attention to them, and I have not had opportunities of carrying out some experiments I projected in connection with them. The practical purpose to which these photometers are put is that of testing the brightness of a very distant light, as exhibited in a lighthouse. And this is done by measuring the thickness of an inky fluid through which the light can be distinguished; or, on the other hand, comparing one light with another, by finding what proportionate thicknesses of the absorbing fluid are required to reduce both lights to a certain low degree of obviousness.

Mr Stevenson has contrived several very convenient forms of this instrument. A description of these will be found in the "Edinburgh New Philosophical Journal" for April 1863.

The question to be solved by such photometers is very different from the illuminating power; and distance in a

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perfectly clear atmosphere would have little effect in altering the penetrating power, provided the angular size of the luminous body were not too much reduced. Thus, if we arrange a liquid, or a series of absorbing glasses, so as to be able just to see a gas-light through them close at hand, we may step a considerable distance backwards before the light becomes invisible, although the actual illuminating power may by so doing be reduced to one-hundredth of the amount at the nearer position. But when the angular extent of the object is very small, as in the case of the planet Venus, a moderate depth of absorbing medium will be sufficient to destroy the image, although the surface be nearly twice as bright as that of a larger object, such as the moon, which may remain still visible through the screen. Vision through a telescope would probably affect the result.

Another question intimately connected with the matter is the richness of each light in those rays which have a maximum facility of passing through the absorbing medium. Sir John Herschel has given a very clear account of this matter in his treatise on Light.

I may make the observation, that as the rays of the lower end of the spectrum are the best penetrators of ordinary fogs, it will be found advisable to pay attention to the richness of the light employed in those less refrangible rays. And for this reason it is probable that the light emitted by burning magnesium would not be found well suited for signal purposes, except in so far as its exceeding portability may be an advantage. It is rich in those rays which have least power of penetrating to a distance in a thick atmosphere, and therefore, other things equal, it would be surpassed for lighthouse purposes by a redder or more orange-coloured flame. This view of the matter leads naturally to our next branch of photometry, in which the chromatic elements of the lights are compared.

Third Branch.—*Analytic Photometry.*

All the proposals for ordinary photometry, or the measurement of the values of different sources of light, are rendered defective by the attempt to treat light, which varies so much

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in its chromatic composition, as though it were constant in this respect, or even as though it were homogeneous. In different lights we have different combinations of an infinite variety of coloured rays, and we can never attain to any precision in our comparisons until we classify these component parts of the light, and compare the corresponding groups.

The full discussion of what would form the best mode of classifying the rays would lead us into the question of what should be regarded as the primary colours; and as a very great deal might be advanced in favour of the views of Young & Wollaston, the discussion might become inconveniently long. I shall therefore pass over this very important matter, and merely indicate what would form convenient screens through which to filter the light, and so render it more or less perfectly mono-chromatic, the object being to compare the amount of each particular colour in one light; as, for instance, the blue, the green, or the red, with the corresponding colour in the other light. And although we cannot give the relative amounts which the blues, greens, and reds severally contribute towards the total illuminating powers, the information gained by such comparative analysis of the lights will evidently enable us to take a very satisfactory view of the character of the particular one examined; and we may approximate to the illuminating powers by always referring our testings to one source of light, and studying the nature and relative values of the colours of the spectrum of that standard.

But it must be borne in mind that the illuminating power of a coloured light is far from being a definite quantity, since, on the one hand, it depends upon the sensitiveness of our eyes to the colours seen, and this is ever changing; and, on the other hand, it rests with the power of the objects illuminated to reflect back the particular rays in which the light is abundant. Thus we might have a room supplied with a splendid light of mono-chromatic yellow, which, in so far as illumination is concerned, might be represented as in total darkness, if all its walls and furniture were of the extreme red and blue colours of the spectrum.

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The standard light to which all others should be referred ought to be well considered before being decided upon. Much may be said in favour of the spermaceti-candle used as a standard by the gas companies. Against this as a standard we have to place—1*st*, The liability of spurious imitations being substituted for so comparatively expensive a material; 2*d*, The low melting point, which causes the consumption and character of the flame to be readily affected by a rise of temperature, as when a glass covering is used to keep off currents of air; and, 3*d*, The changeableness of the light from changes in the length and shape of the uncovered wick.

Perhaps the most convenient standard would be of the nature of that used by Dr Fyfe, viz., an illuminating gas of definite composition burnt at a fixed rate of one cubic foot per hour, in a simple jet having a flame 5 inches high. The difficulty to be solved is the preparation of such a gas.

In fixing upon the coloured screens, equal care should be exercised; coloured glasses would form the most convenient in use, but these cannot be admitted as standards. For standards we should choose definite solutions of fixed salts that can be readily obtained, and fix upon certain thicknesses of these solutions. In the meantime, I suggest the following:—

Screen 1*st*.—To separate the upper half of the spectrum, dissolve 20 grains of clean crystals of sulphate of copper in 6½ drams of distilled water, and add 1½ dram of liq. ammon. of sp. gr. 0·959. This nearly corresponds with the solution of ammonio-sulphate of copper of the British Pharmacopœia, except in having a slight addition of liquor ammoniæ, without which it is liable to become muddy.

Proposed standard thickness of this solution = 0″·2.

This thickness will allow some green to pass, but very much darkened; also, in the case of gas or candle light, some red.

It is, however, better to use a comparatively weak screen, since a darker one renders the photometric observation very doubtful. This screen may be regarded as allowing all the *blue* to pass; that is, all the blue proper, and that also

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which could be produced by mixing some green with the violet.

Screen 2*d.*—To separate the lower half of the spectrum, take a thickness = 0·3 inch of saturated solution of bichromate of potash at 60°. This cannot be admitted as one of the regular screens, as it has no pretensions to be monochromatic, but it may be useful as being the complement of No. 1. It transmits nearly all the red and the brighter green, cutting off the spectrum midway between the lines D and *b*, dulling, however, the extreme red.

Screen 3*d.*—To separate the red rays, we may very conveniently employ the volumetric solution of iodine of the British Pharmacopœia; a thickness = 0·4 inch may be taken as a standard.

Screen 4*th.*—To separate the mono-chromatic green. I have not tried many salts for this; the best I am acquainted with is nitrate of nickel; half an inch in thickness of a saturated solution of this gives a very beautiful green. When the spectrum is viewed through it, borders of red and blue are obvious; but the amount of light from these borders must be very small compared with the mass of green, and a thicker layer need not, therefore, be employed.

The green screens are the most satisfactory to use; there is sufficient light to examine carefully the flames in the Ritchie photometer, and it reduces these to very nearly the same tint, even when comparing daylight with candle-light, it may also be looked upon as giving approximately the *value* of an artificial light for illuminating purposes, as it will rather favour those in which the red and orange do not predominate.

The only final colours transmitted by screens appear to be Wollaston's primaries, viz., *violet*, by great thicknesses of the solution of ammonio-sulphate of copper or other analogous preparation;* *green*, by considerable thicknesses of some solutions of copper or nickel salts; and *red*, by a

* When the ammonia is in great excess, and also in some preparations with carbonate of ammonia, the red of the spectrum is stopped before all the yellow; hence, in thin layers such solutions have a greenish colour, as seen by gas or candle-light.

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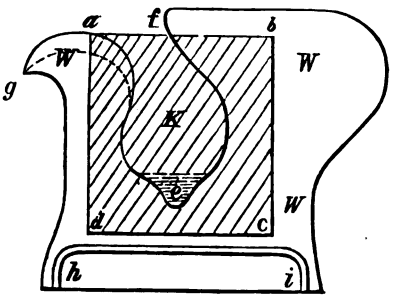
great variety of substances, which in thin layers, by permitting the green also to pass, appear yellow or orange. All simple yellows are, according to these views, white light deprived of violet, or of violet and blue; or, in other words, yellow screens must transmit red and green. It is also in accordance with these views that in our common artificial lights, in which violet is very deficient, yellow appears almost identical with white. But here, again, I am entering upon the interesting subject of primaries—a subject which, I trust, the Society may have brought before them at some early period by our accomplished member Dr Strethill Wright.

The Construction of the Screens.—I have tried a variety of methods of enclosing the liquid between the plates of sheet-glass (which ought to be of Chauce's colourless kind); but all the methods tried are more or less troublesome.

One method is to cut a hole through a sheet of rubber or other suitable material, and tie the plates of glass down after filling the hole with the liquid. This sometimes proves very successful; and should an escape take place, or a deposit form on the insides of the plates, it can be readily taken to pieces and refitted.

Another form is shown by fig. 5; this is very convenient. *W*, *W*, *W* is a piece of hard wood of uniform thickness, in



Side Elevation. Fig. 5.

this is cut a nicked opening, *aef*, and the part at *ag* is hollowed out a little to form a spout, over each face is cemented a plate of glass *abcd;* and the whole is thus

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formed into a sort of pitcher. If the wood be very thin, it will be as well to attach base pieces, *hi*, that it may stand securely. From the shape given at *e*, a very small portion of fluid will be sufficient for an experiment, and when the fluid is abundant the part *k* may be used. The wooden part of the interior should be well coated with the cement used in fixing on the glasses.

It is not necessary in making such a screen to pay much attention to the thickness of the wood; but after being made, the interval between the glasses should be carefully measured and noted down. To render the screen equivalent to any of the proposed standards, the solution must be augmented by dilution in the same proportion that the thickness of the receptacle exceeds the standard thickness of the fluid.* Thus, if the glasses be 0·667 inch apart, and to be filled with the blue solution of which 0·2 is the standard thickness, we must take a certain measure of the standard solution, and increase with water its bulk in the proportion of 0·2 to 0·667.

Notice of some Improvements in the Construction of Theodolites. By E. Elmslie Sang, C.E., Edinburgh.†

In all the examples of theodolites which I have seen, the instrument has been built up of small pieces, fastened together by help of solder and screws. This method of construction was the easiest, if not the only one, that the earlier instrument-makers could adopt, on account of the non-existence of those tools and appliances which, in these days, have so augmented our powers of managing and working large masses of metal.

It will only be necessary for me to mention that, for such an instrument as a theodolite, the stronger, stiffer, and more united the several parts are, the better and more trust-

* This device must not be used in the case of some solutions, which, like that of chloride of copper, change in relation to the spectrum when the amount of water present varies.

† Read before the Society on 14th December 1868.

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worthy will the performance of the instrument be: so that in such instruments there should be as few separate parts as possible.

I have placed on the table two examples of the usual method of building up a theodolite, and two others in which the number of pieces is greatly reduced.

In the first mentioned examples, beginning at the base, we have the three-clawed foot screwed to the outer tube which carries the axis of the horizontal circle. In the larger of the two theodolites it is secured by means of three small screws, and in the smaller one, by means of a screw on the tube. The corresponding parts in the other two theodolites have been cast in one piece.

Next we have the horizontal circle, which in both of the first-mentioned instruments is fitted to its axis, and then held in its place by means of three small screws. This arrangement is convenient for centering the circle on the ordinary dividing engine, but otherwise it is most objectionable. In each of the two other examples the axis and circle are cast in one. And instead of first turning these parts on the lathe, and then transferring them to a dividing engine, I make a dividing engine of my lathe by furnishing it with a large dividing plate screw-racked on the edge; on this plate the parts that are to be divided are fastened, turned, and then divided without being disturbed; the dividing knife being placed in the slide rest. By this means perfect centering and great steadiness in division are insured.

Lastly, we have the upper frame, which is destined to carry the horizonal axis of the verticle circle. In the first two examples, this frame has been made up of four pieces—the axis, the plate to which the axis is secured, and the two standards which are screwed to the plate.

In the two other examples, these four pieces have been cast in one, and by making the plate circular, and bringing the feet of the standards out to the edge, I get the tripod form, which, though not new as applied to that part of the theodolite, is, I think, new in the way in which I arrive at it. I am also enabled to turn the most of it on the lathe.

nother improvement which I take the liberty of bring-

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ing before the Society, is connected with the slow motion. I turn a sphere on the screw shaft of the slow motion, which sphere works in a cup, forming a ball-and-socket joint; the nut in which the screw works is also made spherical, and is placed in a cup; both cups have lids, bearing on their respective spheres, which can be tightened down to the required stiffness. By this contrivance, the uneven motion caused by any want of truth in the turning parts, is entirely removed, and a more pleasant action is obtained.

On Light Railways. By W. J. Cockburn Muir.*

One of the many curious things to observe in the advance of civilisation, is the certainty with which certain products, however rare and costly at their introduction, become, in due time, articles of almost common necessity, by virtue of their meeting certain wants which civilisation itself creates. This is illustrated in the history of a multitude of objects in ordinary commerce and manufactures, which, now within the range of consumption and use of most people, were originally mere luxuries of the rich. What we may perhaps not unaptly term the Law of Assimilation of originally costly means to the common purposes of life, by no means restricts itself to mere personal comforts and conveniences, but operates on the scale of provinces and nations. Its most remarkable illustration, in this view, is the application of steam traction on railways. These were first constructed, as indeed they only could have been, by the wealthiest and most advanced nations of Europe, and by the wealthiest provinces of those nations, then by the United States. Then less wealthy countries, British dependencies, and so forth, emulating their superiors, and catching the infection of new wants, but lacking means withal, came to us for men and for money to build roads, which, being built on credit, have saddled with debt two, three, and four generations of men. In several senses it is fortunate, however unfortunate in others, that the monstrous inflation of credit,

* Read before the Society on 8th February 1869, and awarded the Society's Medal.

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due mainly to a vicious system of raising capital for public works, ended in collapse. We have had breathing time, at least, to reflect on the situation, and to consider whether, and in what way, we can reform the method of procedure hitherto followed in extending the dominion of steam traction.

It is abundantly clear that, so far from our being near the end of railroad building, the ground is only cleared for a continuous extension of what has now become everywhere a necessary method of transit. The Pacific Railway, joining two oceans, is only one of a series, similar in character, yet to come. The branches which must spring from these trunks, as the borders become populated, will end only when civilisation meets its quietus in some at present unimagined catastrophe. The demand for railways is, at this moment, greater than it has ever been. Whatever may be said of Western Europe, there are wide territories of Eastern Europe, of Asia, and of South America, which are waiting to be traversed by the narrow ribbon of railway iron. But even in Western Europe, even in Great Britain, there are districts which are practically cut off from commerce with the rest of the world, from want of railway extension. There are still many towns of considerable resources and population in this country which are ten to fifteen miles from a railroad. Now there are probably few things more difficult to the ordinary mind than to form a just conception of what that must be—to live ten to fifteen miles from a railway station. There being no doubt of the existence of the imperious demand, the important question is, How is the demand to be met? How is this costly thing, now grown to be a common necessity, to be brought within the limits of economical supply? The cost of railways, on the ordinary methods of construction, being absolutely beyond the capacity of many districts sorely in want of them, can that cost be so materially reduced as to make railways possible in such districts at home and abroad? With the hope of advancing somewhat the solution of this question, I venture to submit some general suggestions, as free from unnecessary technical details as may be, for the discussion of the Society of Arts.

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The enormous prices which have been paid for land in Great Britain are purely adventitious, and, therefore, not relevant to the discussion. One need only remark in passing that, as a rule, our landowners, manifesting in this particular infinitely less intelligence than those of countries far less civilised, have acted in fatuous opposition to their own interests and the public weal in making a charge for their land at all.

The whole matter, as regards first cost, may be said to depend mainly on the closeness with which the direction of a railroad can be made to follow, horizontally and vertically, the natural contours of the country to be traversed. Because in proportion to the departure from these contours, is the amount of earthworks, viaducts, and tunnels to be constructed. Now the limit of approximation to the natural contours is of course fixed by the *minimum curve* which can be traversed by the rolling stock, and the *maximum gradient* up which an engine can haul a paying load. These, then, are the two points which it is important first to consider.

As horses dragging a carriage can turn a sharp corner and climb a steep hill, a common road follows, with little deviation, the contours of even a tolerably heavy country. But the characteristic of a railroad is, that being built to meet what (at the present stage of improvements in engine construction) one may venture to call the empirical conditions of the ordinary type of locomotives, such a departure in curve and gradient from natural contours is involved as to entail, even in "average country," earthworks and works of art of considerable magnitude. The range of curve and gradient is still further limited by the practice (none the less vicious for being common) of running express trains at high speed, in which the gross weight hauled is altogether out of proportion to the net weight of passengers. Until very recently a curve of 1300 feet, and a grade of 1 in 80, were considered severe for any but exceptional circumstances. In a common road, we frequently meet with curves of 20 or 30 feet, and gradients of 1 in 6. Surely in these days of mechanical perfection it should be possible to approximate somewhat closer to these than the curves of

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600 feet, and the grades of 1 in 40, which seem now to be considered as the lowest practicable limits for a railroad under ordinary conditions.

In considering the curves as apart from the gradients, we come at once upon the question of the long rigid wheel-base upon which, by mere force of habit, we believe it to be necessary to mount our rolling-stock. In view of the exquisite niceties of adjustment on which we generally insist in our mechanical arrangements, it seems incredible that we should have been so long content to run our engines and carriages upon axles which are not only fixed transversely, but fixed so far apart—from the necessity of the case—that a train has to be ground by main force, with great wear and tear and loss of power, through curves which, with a flexible wheel-base, would be practically as good as a straight line. Moreover, the danger in running with a rigid wheel-base over even a straight road which is in bad repair can hardly be exaggerated.

The impossibility of keeping up the road in the United States over large tracts at the thaw, was probably the main circumstance which brought about the use of the "bogie." Inasmuch as this affords to American rolling-stock a long flexible wheel-base, capable of traversing freely extremely sharp curves, besides being tolerably safe over a rough road, it is, at all events, in advance of our European method. But the bogie-truck is far from being a satisfactory solution of the difficulty. Mechanically considered, indeed, it is a mere clumsy expedient, giving great extra weight to the engine and carriage, whilst leaving the stability of the body unprovided for.

In travelling over a bad road, or indeed a good road, if at high speed, the oscillation of the car is like that of a rolling ship in half a gale of wind; while the tendency of the bogie-truck itself, being only connected with the car by the centre-pin, is to run wild at especially rough spots, mount the rail, turn at right angles, and bring all up standing. Hence the necessity for the short check-chains between the truck and the car.

The mere pivoting of an axle, or set of axles, may be

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therefore set aside as no final solution of the problem. That solution is only to be found in a method of so connecting a set of axles, that they shall necessarily radiate to the centre of the curve on which they run, while, at the same time, the body of the carriage shall be kept steady. Several plans to effect this have been propounded. They are, however, generally vitiated by complexity of construction, or impractical details. For example, the articulated trains of M. Arnoux on the Paris, Sceaux, and Limours Railway, however fearful and wonderful in conception, involve features which can never be accepted as elements of a type for general application. (An excellent description of the plan is given in "Engineering" of 22d January.)

The only system, so far as I know, which fulfils the practical exigencies of the case with simplicity and efficiency, and without really adding to the weight of the vehicle, is that by Mr Claxton Fidler, F.R.S.S.A. As he will probably himself bring the subject before you at an early opportunity, it is only necessary at present to explain that, by using three axles, or three pairs of axles, which are connected together by a very simple arrangement, he obtains a flexible wheel-base of any required length, capable of rolling freely round a curve as sharp as 50 feet radius, or less, if necessary, the connections compelling them to radiate to the centre of the curve. The plan is also applied to the engines, without interfering with the ordinary arrangement of the working parts. For example, in the case of a four-coupled tender engine, an articulated frame on four wheels takes the place, aft of the fire-box, of the uncoupled trailing wheels of the engine and the leading wheels of the tender, and is so arranged as to compel the various sets of axles to radiate on a curve; the length of rigid wheel-base being reduced to the distance apart of the coupled wheels.

The advantages of such a system in the case of a badly kept road are far superior to those of the bogie-stock, inasmuch as while the sinuosities of an irregular line are smoothly traversed, the body of the car is kept perfectly steady, and there is no inherent tendency to leave the track. I lay particular stress on the contingency of a bad road, because, as

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all practical men will perfectly understand, it must be accepted as more or less certain to accrue in the case of light railways, constructed in outlying districts, or sometimes indeed traversing tracts of little-frequented territory, or subject to the disorganising effects of thaw after continued frost, or it may be, of tropical rains.

In view partly of this contingency, but chiefly of the notably reduced radius of curvature which is an essential condition in the theory of light railways, the method of coupling the vehicles of a train is an element of no small importance. If we take two ordinary trucks, with say ten feet wheel-base, and couple them in the ordinary manner, we shall find that it is impossible to pass them from a curve of 165 feet radius, for example, to a reverse curve of the same radius, with no intervening straight. The leading wheels of the leading truck leave the track on entering the reverse curve. The reason of this is that the tight coupling at the ends prevents them from sliding past each other, for adjusting the positions of the frames to the trend of the two curves. But if a segmental piece of timber, the curve of which is struck from the centre of the nearest axle, be fixed on the ends of similar trucks, coupled together by a straight bar pivoting over the centres of the axles nearest the ends, the trucks will pass through what platelayers would call the "kink" with perfect freedom, because the truck-ends can slide over each other. This system was invented by Mr Fairlie, whose special attention to these subjects is well known. As the coupling rod is pivoted, the one end over the centre of the trailing axle of one truck, and the other over the leading axle of the other, it of course traverses over the head-stocks of the frames when these are on a curve, while the segmental head-stocks themselves slide one round the other. A palpable advantage, in view of light railways, is that the hauling strain is carried by draw-bars down the centre of the whole train, so that the frames of the trucks are relieved of a large amount of work, and may therefore be made with lighter scantlings. The close coupling also prevents the jamming and jolting at starting or stopping, and changes of speed or gradient.

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The abolition of side buffers may be assumed as a consequence of the adoption of sharp curves, and correlative rolling-stock with flexible wheel-base. The combination of the method of coupling just described, or some modification of it, with Mr Fidler's articulated frame and radial axles, will be found, I believe, to fulfil all the practical exigencies of the case.

We may, I think, safely assume that by the adoption of either these or kindred methods, the limit imposed on the radius of curvature by the nature of the rolling-stock ceases to exist; except in those regions of routine or prejudice where the shadows of old ways are accustomed to linger. This being admitted, the only other limit to excessive curvature is the increase of length in the whole road. Now, as to save a *détour*, we may have to climb the sides of a hill more or less steep, we come to the consideration of steep gradients, not apart from, but coincident with sharp curves. That is to say, having found the practicability of flexible base, we have to inquire what means are available for obtaining sufficient adhesion on the rails for the engine to haul a load equal at least to its own weight, which may be taken roughly as the limit of economic work.

It is perhaps hardly within the scope of the general subject of light railways, to consider those exceedingly rare cases, in which a grade of 1 in 10, or thereabouts, becomes a necessity. I may, however, be permitted to advance the opinion that neither the imperfect success of the *central rail* on the Mont Cenis Railway, nor its inherent mechanical difficulties, can leave us free to suppose that it is likely to be accepted by what I would call the advanced technists of the present day, as a satisfactory practical method of mountain climbing. Indeed, from the abstract point of view, this rail standing up in the middle of the track, with all its concomitant fixings, complicated level crossings, and still more hopelessly complicated locomotive, appears to be nothing short of an abortion. From this point of view, one would almost rather see all the axles in the train connected by gearing, after one or other of the several not very complicated plans propounded by various engineers, so that all the wheels being

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converted into driving-wheels, the train might climb by fair straightforward adhesion on the plain uncumbered track.

A very remarkable method of mountain-climbing has been invented by Mons. Agudio, an Italian engineer of great eminence, and has been at work at Dusino for some years, with unfailing success. An illustrated description of the machine was published in "Engineering" of 6th Dec. 1867, from particulars which the editor was good enough to accept from me.

The general outline is that power is transmitted from stationary engines, which may be actuated by the abundant water of mountain districts, along an endless rope passed round a horizontal drum at each end of the incline, to a locomotor of ingenious construction, on each side of which are suspended vertical drums. The rope takes a bend round each of these, which in their turn are connected by gearing with coupled wheels. The rope is in fact a driving-band. The locomotor obtains adhesion for hauling the load, partly by the gripe of the driving-wheels on the rails, partly by a reciprocating clutch which grasps a dead rope lying between the rails. The published descriptions show the application of the method to the Fell mid-rail, which takes the place of the dead rope. Mr Agudio informed me that he had made an offer, in which I believe he was supported by the French Government, to work the traffic of the Mont Cenis Railway at a notable reduction of the present cost. The theoretical analysis of the system certainly shows remarkable haulage capacity, and where sufficient water-power is available, the economy as against steam traction is evidently considerable. A rope used in the ordinary way has to bear the whole strain of haulage, but in this case the tension is so reduced that a steel rope of very small diameter is amply sufficient.

However daringly heterodox the opinion, I confess that the supposed necessity for what has been called "artificial adhesion" appears to me to be the offspring of chimæra. The vagueness of the notions which have prevailed on the general subject of adhesion until very recently, and indeed still prevail, was singularly illustrated in the delusion which led one

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of the most scientific engineers of modern times, the late Mr Brunel, to suppose that when once the Great Eastern steamship was started on the slipway, she would glide into the water so easily that it was necessary to erect, for checking her, those windlasses whose gigantic proportions will be remembered by all who saw that futile and costly attempt at a launch. An exhaustive series of experiments on the adhesion of iron *rolling* on iron, under given insistent weights, at given inclinations, is still a desideratum to fix with certainty the mathematical conditions of locomotive adhesion on heavy grades. A general review even of this subject would itself require a paper of some length. Nor is it necessary for the present purpose to do more than assume, what we are perfectly justified in assuming, that gradients down to 1 in 15, or even 1 in 12, are capable of being worked economically with honest straightforward gripe on the rails, by adding to the normal weight of the engine that of a portion or the whole of the load to be hauled.

But surely, when the worst comes to the worst, we ought to be able to climb Alps by a fair tread on the road, in place of being driven to such an expedient as a mid-rail, which neither *prima facie*, nor as a mechanical reality, bears the character of a legitimate solution of the difficulty. If, for example, we had to work a grade of 1 in 6, is there any reason why the locomotive should not be provided with an extra pair of driving-wheels of wider gauge than the track, tyred with vulcanised rubber (as adopted with such success by Mr Thompson in his traction engine) to run on a tram of blocks of stone or rough-faced cast-iron laid outside the common rails of the track, thus gaining adhesion by the nature of the surfaces in contact, apart from the distribution of weight? As a general question, it seems to me that the difficulty is not so much how we are to get up the hill, as how we are to get safely down by the application of sufficient brake-power to the flexible wheel-base.

Grades heavier than say 1 in 20 can, however, only occur in exceptionally mountainous country. For the general question of light railways, we may assume 1 in 35 to 1 in 30 as the maximum. Now, in approaching these limits,

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the length of rigid wheel-base of the ordinary type of locomotive increases so rapidly, from the necessity of distributing the increased weight of a more powerful engine over a great number of coupled wheels, that the passage of the sharp curves, which are one of the conditions of a light railway, is out of the question. For hauling heavy loads, there appears to me to be, therefore, no escape from the alternative of mounting a long boiler, with its supply of water and fuel, on two steam bogies of short wheel-base, as is done in the now well-known engine of Mr Fairlie. There is no other arrangement by which we can obtain at once the necessary engine-power, and the necessary adhesion, without so increasing the weight on the rail at a given pair of wheels as to imply a costly track capable of standing the terrible tear on the road. The proposition that such work as is now referred to may be done efficiently and economically with two engines coupled together, is, I believe, untenable. Such an expedient is precluded, on light railways at least, by the cost alone. Moreover, we require for hauling heavy loads on heavy grades round sharp curves, an engine with long steady wheel-base, and which will run equally well forward and aft; both of which conditions are met by the Fairlie engine. Its centre of gravity must necessarily always travel on the axis of the track; and, consequently, we find that even over a bad road it runs with remarkable steadiness. It must be borne in mind that, owing to necessarily different methods of connection, the steam bogie runs under very different conditions from the ordinary bogie-truck under a car. Another great point achieved is, that we get rid of the dead weight of the tender, without being landed in the difficulties involved in the attempt to adapt the tank-engine to exceptionally heavy work.

In the steam omnibus designed by Mr Fairlie for working surface tramways with grades of 1 in 12, the whole load of passengers and their baggage is utilised for adhesion. Light goods traffic may be worked on the same plan. Another method for working ordinary passenger traffic over either ordinary or light railways, is being introduced by Mr Samuel, whose achievements on the Eastern Counties Railway are

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well known, conjointly with Mr Fairlie; the main purpose of which is to reduce the present outrageous disproportion between dead and paying load, chiefly by making a portion of the load available for adhesion. A small engine, with a vertical boiler of high generating power, is mounted on four coupled wheels. A long carriage for eighty passengers is carried at the leading end by the engine, the frame being continued along the engine frame, and connected in such a way with the vertical circular boiler as to work round it like a collar. The boiler itself thus taking the place of the usual bogie-pin, gives perfect steadiness to the leading end of the car. The trailing end is mounted on a common bogie. Having a flexible base of 45 feet between bogie-centres, this steam-carriage can yet turn a curve of 40 feet. The total weight loaded, including the engine with 9-inch cylinders, is only about 20 tons, about three-fifths of which are good for adhesion. Such a train may be worked with ease at a moderate speed up a grade of 1 in 30. The only objection to the plan is the oscillation which may occur over the trailing bogie over a bad road, or running down hill.

A somewhat similar train is proposed by Mr Fidler, to be mounted on his articulated frame. It has, however, the disadvantage, that the engine is in the centre, the passenger cars being at each end.

As a general result, this much is demonstrable—that for all the contingencies contemplated, we can obtain the required tractive and adhesive power, with flexible base, without loading any axle with more than 3½ to 4 tons. This leads us to the consideration of another point of vital moment.

If at one pair of driving-wheels we have a weight of 14 to 18 tons, which must be the case with the common type of engine, it is clear that the track and all the underworks must be of a strength at all points to support that weight, with the crushing and grinding force at running speed which it implies. If we reduce the weight insistent on the rail at any pair of wheels to 8 tons, it is equally clear that we may in like proportion reduce the strength of under bridges and the weight of the rails. We have here, there-

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fore, another direction in which tangible saving may be effected in first cost.

The clause in the Railways Regulation Act of last session relating to light railways, limits the weight at a pair of wheels to 8 tons, and the speed to 25 miles. For these conditions a rail of 40 lbs. has come to be accepted as sufficient. The rail is of course flat-footed, as universally used abroad, and gaining ground rapidly at home. We may at last be said to have convinced ourselves that the turning of a double-headed rail is a delusion, and that before long that form will be relegated to the museum of railway antiquities.

There is room for the discussion of the question, whether the light rail should be laid according to the Vignoles' system on timber cross-ties, or on cast-iron sleepers. The Society is already aware, from a previous paper, of the grounds on which I advocate the construction of the track wholly in iron. That method becomes, I apprehend, doubly imperative in the case of a light rail for a light railway, because we can compensate for the reduction in strength of the rail, which is costly, by a proportionate increase in the bearing surface of the iron sleeper, which is cheap.

The decrease of expenditure in maintenance and renewals also is of paramount importance. At a future opportunity I hope to communicate to the Society the particulars of a further improved iron sleeper, which I have designed expressly for use with the flat-footed rail on light railways. The fastenings are exceedingly simple, discarding bolts and nuts, and obviating the objectionable punching of the rail. This track can be laid at a less cost than the "Vignoles' road."

It is a curious coincidence that whilst we, in this country, are doing our utmost to reduce the weight on the driving-wheels of the engine to near the 3 or 3½ tons only, which are carried at the wheels of all the other vehicles in the train, in order to lessen the destruction of the track, a scheme is propounded in France by MM. Bournique and Vidard, for increasing the weight at the wheels of the trucks and carriages to near that on the engine driving-wheels. This is effected by mounting a long truck on an

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articulated frame with four wheels wide apart. The load on an axle is about 12 tons. The argument is, that as the whole road is built for carrying the greater weights of the engine, which weights are the measure of capacity of the road, the loading of the train-axles to only half the amount is running to waste. This seems equivalent to a proposition that, having done wrong in one particular, we should rectify that by plunging deeper into error. Because, evidently, the road must suffer in proportion to the increased number of points carrying the maximum charge.

The moderate speed which will be sufficient for all exigencies of light railway traffic, is another element bearing directly on the weight of rail and strength of underworks. It is the *pace that kills*, not only the track and the rolling-stock, but the shareholders' dividends. The valuable statistics compiled by Mr Price Williams show clearly the enormous increase in the wear of the rail under high velocities. The limitation, under heavy penalties, to 25 miles per hour, in the Act of Parliament, is therefore in every sense a wise provision.

With reference to the *gauge* on which light railways may be constructed, I am persuaded that great misapprehension exists, from want of due consideration of the details of the question. It is so easy and natural to jump to the conclusion that reduction of gauge and reduction of cost must be coincident, that it is accepted without more ado. But what are the items of saving as between the practically extreme gauges of 3 feet 6 inches and 5 feet 6 inches? Not the 2 feet width of land, because landowners may rest assured that, for the future, if they want to be put in communication with the trunk lines of the country, they must give the land without charge, and think themselves fortunate in the opportunity. Abroad, as a general rule, land required for railway extension is now granted free, as a matter of course. Not the size of the tunnels, because, by the terms of the whole argument, there are to be none. Not the width of bridges, because we begin by reducing their number and magnitude. The remaining saving of 2 feet (as the extreme case) in the length of cross-girders, &c., is a bagatelle. Not the width of the track,

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because with iron sleepers the gauge is practically immaterial in cost. Not the rolling stock, because its cost is in proportion to the width of body, not the length of axle. In fact, in this item there is more likely to be loss than gain by reduction of gauge, because below the limit of width of 4 feet 8½ inches rolling-stock it is difficult to devise economic stowage of either passengers or goods, but especially the former.

As regards the working of curves, a flexible wheel-base being conceded, the gauge is absolutely of no moment. In brief, the fact must become plain on close examination, that a light railway may be constructed with wide gauge every whit as well as with narrow.

My own conviction is that, as a matter of public policy, it is in the highest degree inexpedient to suffer a departure, except in peculiar cases of special tramway, from whatever may be the already established gauge of a country. Otherwise we preclude the possibility of connecting all the lines of a country in one system at any future period, when that should become desirable, from the development of traffic and resources. In this view it is essential to bear distinctly in mind, that in cases where a light railway becomes, certain years after its first construction, inadequate to the increased requirements, all that we have to do is to put in stronger bridge-girders from time to time, and renew worn-out light rails by a heavier section. Again, referring particularly to our own country, a break of gauge involves breaking bulk and transhipment of freight to an extent utterly inadmissible.

It is necessary here to add a qualification to what I have already indicated as the limit of curvature. Where a light railway branches from a trunk-line, we must assume that the ordinary freight-trucks will have to traverse the light line to save transhipment of freight. Taking the length of wheel-base of a goods truck at 10 feet, the sharpest curve which could be used would be of say 300 feet radius. It would be necessary with this radius to insert a short length of straight between reverse curves; as otherwise, with the common system of coupling and buffers and rigid wheel-

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base, there would be risk of the trucks being thrown off the road at the change or "kink." As the weight on the axles of ordinary trucks rarely exceeds 7 tons, they are, in this respect, within the prescribed limit.

The length of wheel-base of ordinary passenger-cars is usually so much greater than that of freight-trucks, that they would be shut out of a line with curves even so flat as 300 feet. Consequently, in passing from a trunk-line to a branch, passengers must change carriages—a matter of so common occurrence and small inconvenience as not to be worth considering. Main-line engines of the ordinary type are, of course, excluded by the excess of weight on their axles.

On the other hand, with a uniform gauge, all the rolling stock of the light railway may, if need be, traverse the trunk-line. The three gauges of 4 feet 8½ inches, 5 feet 6 inches, and 6 feet, are at present supreme in the extent of territory covered. The last is too wide, but the two first are exceedingly convenient dimensions for the road-works, for allowing economic stowage of freight and passengers in the corresponding width of vehicles, and also for the emplacement of the working-parts of the locomotive. It is difficult to see what is to be gained, either economically or technically, by seeking to renew an interminable confusion of gauges over the now happily prostrate corpse of the 7 feet giant of that ilk.

In the observations which you have permitted me to offer, I have endeavoured to indicate for discussion the general considerations upon which the matter depends, omitting, as far as possible, unnecessary details, which are understood as of course. We may now formulate—what we could hardly have done at the commencement—the general definition of a "Light Railway."

The terms of this definition may be stated thus,—

1*st*, That to avoid tunnels and effect material saving in earthworks and bridges, the route shall adhere closely to the natural contours of the country; with a general curvature practically limited only by the addition to the total length, and particular curves traversable by a rigid wheel-base of 5 feet, or in some cases 8 to 10 feet; and with gradients along which an engine with flexible wheel-base, utilising a part or

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the whole of the load for adhesion, can take double its own weight at a low speed.

2*d*, To effect economy in the first cost, and working wear of the track and underworks, that the greatest weight insistent on the rail at any wheel of the train shall not exceed four tons, and that the rate of speed for trains shall not be higher than 25 miles.

3*d*, That the gauge should conform to that already established in a given country.

It is unnecessary to include in the definition what follows from it as a corollary, viz., that the common types of rolling-stock, with, perhaps, the exception of the freight-trucks, are inapplicable. The paramount exigencies of the extension of steam-traction in directions only recently contemplated, demand forms of greater scientific refinement. Apart, indeed, from the mere question of impracticable wheel-base, there is in our ordinary rolling-stock a palpable running to waste in the disproportion between the paying load and the weight of dead stuff to carry it, which would be incredible if the facts did not stare us in the face. On a common road, the proportion between paying and unpaying weight, horses included, is rarely over ton for ton. There are railways where the net weight of a carriage, with an allowance for engine, is, when full, six tons to one ton of passengers. But a full carriage is an exceptional case; and from the Board of Trade statistics, so ably summarised by Mr Smiles in the "Quarterly Review" of October last, it is demonstrably below the mark to say that, taking the average of the whole country, for every ton of passengers hauled a train mile there are thirty tons of train weight, including the engine with its ponderous drag of tender. On many branch lines, therefore, the proportion cannot be less than sixty to seventy tons to a ton of passengers.

It is little wonder, then, that dividends fade at the end of portly financial statements into thin figures. The fault does not lie, however, with engineers, but with the public—the irrepressible public, who have no conscience where railways are concerned, and demand, regardless of cost, space to recline *en grand seigneur*, and high rates of speed. In the

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rolling-stock, as in the track, it is still the pace that kills. There is, however, ample assurance in the active attention now paid to this matter, that we shall succeed before long in reforming it altogether, to the notable advantage of all concerned.

There remain one or two points of some consequence in view of first outlay and working cost, to which brief reference may be made.

The elementary notion of a light railway being that it shall serve traffic intermediate in magnitude between that of an ordinary railway and a common road, it follows that a single line, with occasional sidings and passing places, is sufficient. The nature and extent of station accommodation must also be kept strictly within the limits of the absolute needs of the traffic, *in the first instance*,—extension of the accommodation being effected from time to time, as the traffic grows, and can pay for its own house-room.

In this country, at least, the land has such intrinsic value, that whether obtained free or by purchase, the width taken need be little more, on the average, than that necessary for the road-bed and side-drains; because the whole theory of construction assumes a line practically on the surface.

The number of stopping-places must be sufficiently numerous to pick up traffic at the principal roads crossing the line. To facilitate frequent stoppages, without waste of time and steam-power, each station should be located at the summit of a rising grade each way of about 1 in 30, and 80 to 100 yards long,—as proposed, I believe, by Mr Brunlees, to be adopted on the new London and Brighton railway; abandoned for the present. Roads would, of course, as a rule, be passed on the level. By the adoption of long cars on flexible wheel-base, and having a fore-and-aft gangway instead of side-doors, the train-conductor could serve tickets on board, dispensing with all ticket-office superfluities.

With low speed, light weights, and flexible rolling-stock, the tendency of the sleepers to motion in the ballast is palpably reduced. A lower quality and less quantity of ballast may be therefore admitted, effecting in many localities a tangible saving.

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The general result is a saving of about two-thirds of the first outlay, as compared with ordinary railways; that is to say, that a light railway may be built and completely equipped for from L.3500 to L.5000 per mile, according to the nature of the country and its distance from the source of supply of track materials and machinery. It may be contended, by those who have not paid special attention to this subject, that the advantages of economy in first cost are lost in largely increased working expenses due to the heavier grades assumed. But granting this increase, for the sake of argument only, it may yet be easily shown (if it be not at once apparent), that it would be more than compensated by the saving of interest on the capital sunk in heavy works at the outset, and on capital borrowed at high rates, for doing what is beyond the legitimate resources of a given district.

But the large increase in working expenses cannot be admitted to exist as a necessary consequence, for several reasons,—1*st*, Exceptionally heavy grades can only be of rare occurrence, and when they occur there is no difficulty in utilising a considerable portion of the load for adhesion, which, with ordinary long trains, is impracticable. 2*d*, The proportion of unremunerative to remunerative load can be materially reduced with such facility on a light railway as to afford, even with gradients heavier than usual, a sensible diminution of the present ratio of working expenses to gross receipts. 3*d*, It is capable of demonstration that a line constructed for light traffic, with heavy grades, at a low first cost, gives a lower final result of working cost, taking into account the saving of interest on capital, than a line built at heavy cost, with light grades, for light traffic.

Notes upon the Question of Ruling Gradient as affecting Light Railways. By T. Claxton Fidler, London.*

The determination of ruling gradient is affected by two conflicting considerations, viz.—that of economy in prime

* Read before the Society on 8th February 1869, and awarded the Society's Medal.

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cost of works, and that of economy in working expenses; and in proportion as economy is attained in one direction is it sacrificed in the other. Clearly it is possible to err in either direction; and there must be for any particular case a gradient which, better than any other, steeper or flatter, fulfils the various exigencies of that case, and which might be called the *ruling gradient of greatest economy.*

This gradient will evidently vary according to the topographical and geological character of the district to be traversed, of which nothing can be said *a priori;* but will also depend upon the *amount of traffic to be accommodated* —for it is clear that between two proposed ruling gradients for any given line, while the extra expense involved by adopting the flatter one is a constant quantity, and therefore also the annual charge for interest on that extra capital—the saving in working expenses which is thereby effected is in direct proportion to the number of trains per annum. So that for a *heavy* traffic the saving effected may be *greater,* while for a lighter traffic it may be *less,* than the expense incurred for the sake of that saving.

Of course, this might be shown algebraically—putting y = total annual cost = a sum of two functions of x the rate of ruling grade, of which one would express the variable annual charge for interest on cost of works, and would contain x as a denominator or as a negative quantity, and the other would contain x as a numerator, and would express the variable annual working expenses. And by differentiating, a value of x might be obtained, which would give the minimum value to y. But as it would be impossible to fix the numerical coefficients, such an analysis would serve no practical end. It will be more to the purpose, to show broadly the influence of this consideration by taking two extreme cases.

Suppose a line through a given district to have a traffic of 40 trains a day, or say 12,000 trains a year, and suppose the line to be built with an easy ruling gradient at a cost of L.10,000 a mile—interest on which at 5 per cent. = per mile per annum, ... L.500

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And suppose the working expenses 2s. 6d. per train mile, 12,000 train miles	=	L.1500
		L.2000

If, by adopting a steeper ruling gradient for this line, the prime cost had been reduced to one-half, or L.5000 per mile, and the working expenses doubled to 5s. per train mile, *no* economy would have been effected—for,

L.5000, at 5 per cent. interest	=	250
And 12,000 train miles, at 5s.	=	3000
		L.3250

which is > 2000 (Case I.).

But if the traffic were a light one of 4 trains a day, or say 1200 a year, it would cost annually on the heavy line with easy gradients—

L.10,000, at 5 per cent. interest	=	L.500
1200 train miles, at 2s. 6d.	=	150
		L.650

And on the cheap line with heavy gradients—

L.5000, at 5 per cent. interest .	=	L.250
1200 train miles, at 5s. .	=	300
		L.550

which is < 650 (Case II.)

and an economy *would* be effected.

The result of long and costly experience has been hitherto that our engineers have gradually adopted even for *trunk lines*, gradients of continually increasing steepness—and the practical inference that may be drawn from the above consideration is, that *if now*, as the result of a system of trial and error, we have at last approximated to the most economical method of constructing *trunk lines*, and have practically determined for such lines the "ruling gradient of greatest economy," or the extent to which prime cost should be cut down at the expense of the locomotive department, then it must be apparent that for branch lines and lighter traffic,

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the prime cost ought to be reduced to a still greater extent, and that the "ruling gradient of greatest economy" for such lines will be found to be still heavier.

Reflections on the Water Distribution within the City of Edinburgh. By EDWARD SANG, F.R.S.E.*

The present state of discussion as to the water supply of Edinburgh seems to me to warrant my attempting to draw the attention of the Society of Arts to the subject, and particularly to that part of it which relates to the distribution of the water within the city. For the purpose of fully explaining my views, I shall take a glance at those circumstances in human society which render such supplies expedient, and which furnish the principles for their regulation.

In the first stage of the growth of a town, while it consists yet of only a few houses, each individual family has to provide its own supply of water, which is carried from the adjoining rivulet or spring, pumped up from wells, or perhaps collected in tanks from the rainfall on the roofs.

As the village grows, the duty of bringing in the water is delegated to water-carriers, who sell the commodity, the value of which is just that of the labour of transporting it. Some of the neighbouring springs acquire a greater reputation than others, the water from them fetches a higher price, and the right of supplying it becomes vested; hence the origin, partly, of the ayasmas in the East, and of the ancient penny-wells of our own country. At first bags are sufficient, carried on men's backs; then by horses; and at last water-carts are used for economy. Varieties in the situations of towns necessarily cause variations in the mode of supply; but during all these elementary conditions of the matter, each family has to purchase, either by actual or by vicarious labour, the water necessary for its wants, just as it has to provide its food or its clothing.

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* Read before the Society on 8th March 1869.

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When the town has grown large, the nearer supplies of water are insufficient; the smoke has ruined the roof-supplies for all culinary purposes, and it becomes necessary to concert measures for obtaining water from a greater distance, and for storing up the excess of water which falls during the wet season, in order to compensate the deficiency during the dry. The transport of water from a distance is most economically performed by means of conduits or of pipes; the storage requires the construction of large dams or reservoirs, and these imply the expenditure of much labour and capital.

If the water-works be executed by enterprising speculators or by private companies, these must look for a recompense in the sale of the supply; they take the place of the porters and carters merely in virtue of the greater cheapness with which they supply the article; the manner and conditions of the sale are matters for private arrangement, and are subject to the laws of all other commercial undertakings. The water company desires profit, the citizens look for cheapness, certainty, and purity, and the conflicting interests effect, as in other cases of bargaining, a compromise. In such a state of matters, when capitalists are, as yet, free to import water as they may happen to be able, it is the interest of the citizens that the trade be over rather than under remunerative, because, while the over-payment can only cause a slight inconvenience, the want of a supply may entail ruin. It is, therefore, and always has been, the part of the citizens to offer advantages and inducements to those who are willing to undertake the supply of water: they desire to have this supply too great rather than too small. The water merchant has thus a natural advantage over dealers in other commodities.

The situation of many towns in regard to the available sources of water is such as to give virtually a monopoly to those companies who have secured these sources. When cities grow very large, this is almost inevitably the case; and then a feeling of antagonism arises between the purchasers and the vendors of water. The regulating powers of the general state government are then appealed to. Under this super-

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vision, sometimes the municipality undertakes the work, the expenses being laid in certain fixed proportions on the inhabitants; sometimes the work is delegated to one or more water companies or trusts, subjected to fixed regulations; and at others, though rarely, the general government undertakes the duty.

In whichever way the thing is to be done, the distribution of the cost among the inhabitants, and that too of the water, form the chief and obvious subjects of legislation. The distribution of the water is by far the more important of the two; it is, in fact, the root of the whole affair. The proper supply of water to each individual family was the aim and object of the whole undertaking.

When towns have grown old, the cost of their ancient aqueducts has been forgotten, the water brought by them becomes the common property of the citizens, and the insignificant expense of repairs is all that has to be provided. Even here, where there may be said to be no cost, the fair and equitable distribution of the water is a matter for serious consideration, more particularly in seasons of scarcity. The question is how to regulate the supply so that it may be proportioned to the wants of the various districts.

We may learn something in this respect, by examining the mode of distribution in the old city of Constantine, where the prime cost of the aqueducts and reservoirs has long since been lost sight of, where there is no water company, and the whole matter is in the hands of the government. In order to send to each of several districts a supply proportioned to their wants, the water is run into a tank, in the sides of which notches of different lengths are made, all having their lower edges on the same level, and the water which flows from these notches is led by pipes to the several districts. By this means, whether the supply be abundant or defective, the various mahals are rateably supplied, and no one district can have a complaint against another. The place where the division takes place is called the Taksim,*

* This word *taksim* is interesting to the English etymologist, as furnishing two words to our language; the Arabic word or root *kysm* signifies separation, hence *kasm* (chasm), a rent in the ground; its derivative *taksim* means the

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and is sometimes rendered conspicuous by the necessity of erecting tall pillars to carry the distributing tanks at the proper level. In each mahal or district, there are several cheshmés or fountains, from which the water is served by sakas or water-carriers, who are paid at the fixed rate for each skinful, and whose duty it is to see, particularly in dry seasons, that each house receive its fair proportion; and I must do these sakas the justice of saying that complaints of their partiality, even in trying seasons, are very rare.

Here we have an attempt, and practically a successful one, to allot the supply of water proportionally to the wants of the inhabitants, and to make the burden, or what we would call the water-duty, fall fairly and justly upon the consumer. Like every other equitable arrangement, this one carries with it collateral advantages. It encourages carefulness, and completely puts an end to wilful waste. The householder is induced to collect the roof-water for the purposes of clothes-washing, and to sink a well from which he may draw water unfit for drinking, but fit for that important and often practised operation, floor-washing.

From this introductory matter, let us turn to the arrangements of our water supply in this city.

Here the municipality has shrunk from the task of bringing in the supply of water, and has induced an independent body, a water company, to expend the requisite capital. Of course, inducements were held out to capitalists, viz., the expectation of a good return for their money, which is the only inducement capable of influencing monied men in their character of capitalists. The arrangement was perfectly legitimate and fair, and its natural result, that the Water Company enjoy a handsome dividend, is simply the realisation of the inducement originally held out; so far from being a cause of complaint to the citizens, it is a matter for congratulation. In what condition should we find our-

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place or act of separation, and supplies us with the word *tax*, expressive of the distribution of a burden; perhaps it also is the origin of the word *task*, by the not unusual transposition of these letters, as in *axe* for *ask*.

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selves if the Water Company's shares were unsaleable? But though fair, the arrangement was most injudicious; because it created an opposition of interests, where there might have been a coincidence; it also prevents the gradual absorption of the first cost. As an obvious example of the inconvenience of the arrangement, I may cite that part of it which prevents the sale of water by any but the Water Company, and so hinders us from making use of other supplies which may be at hand; such as the canal water, for the use of steam engines. At the same time, it must be admitted that the directors of the Water Company have not acted always as mere capitalists, but that they have combined to a great degree their duties as citizens with their duties as directors of the company.

A far greater inconvenience than the abstract one of having a water company at all, an inconvenience which would be felt even though the works were taken out of the Company's hands and vested in a trust, lies in the distribution of the water, and the incidence of the water-rate.

Each householder contributes in proportion to his rent. Now the rent may, in a rough way, be taken to represent the quantity of water likely to be used, and so this apportionment of the burden is sufficiently near to a just one for all the purposes of municipal government. It is accompanied, however, by this awkward drawback, that it offers no inducement to carefulness; whether we use much or little matters not, we have the same to pay. Were the supply inexhaustible, there would be no inconvenience from this, but with a limited supply the inconvenience becomes a serious one. The theory of the arrangement is this, that any one is at liberty to draw off as much water as he pleases, and that, for this liberty, he pays according to his rent. Taking the great mass of the community, I believe that the deliberate intentional waste is almost nothing. The waste, however, from misapprehension or ignorance, is very great; that from sheer stupidity perhaps greater still; for it must be recollected that one stupid person, by leaving the pipe open, or by deranging the waste-pipe in the cistern, will cause a loss sufficient to counteract the carefulness of several hundreds of the neigh-

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bours. There is here no definite relation between the payment and the quantity.

But there is a still greater inconvenience in our present arrangement: it is in the division of the community into two classes, the one paying by measure, the other paying by rent; the one paying for what water they may use, the other paying whether they get water or not—an inconvenience aggravated by the circumstance that those who do not pay according to quantity may waste as much as they like when they can get it.

The essential injustice of this arrangement, and the danger of its misuse, were so apparent, that the framers of the measure sought to modify it by a provision, that the company shall not sell water to manufacturers until the householders be fully supplied. Nothing can be more fair on the face of it than this provision, because the whole security for and inducement to the original outlay was in the water-rate; and therefore, since the water-works were virtually constructed by them and for their behoof, it was only just to see that the wants of the rate-payers should be first attended to. Yet nothing can be more illusory than that provision.

A manufacturer, a brewer, a distiller, an engineer, or a printer, applies for water in the winter when the dams are filled to overflowing. The water is laid on, the meter is busy recording the number of cubic feet when the dry season arrives. What is to be done? According to the strict letter of this provision, the manufacturer's supply should be cut off. But then both the pecuniary interest of the company and the dictates of common sense say no; for if the engine were to stand still, the work people would go idle. Hence the inevitable result of the increase of our population and of our manufactures is, that while the water continues to flow through all the meters, it is intermittent in the houses. It is true that the interest of the Water Company seems to lie on the side of this evil, and it is therefore easy for us to blame the company for its existence. But when we look more closely into the matter, we shall see that the company is powerless to remedy it, and was innocent as its originator.

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In the first place, were there to be no manufacturers within the city? If there were, how is their water supply to be regulated? Rental can be no guide; the brewer needs much, the printer needs little. The supply by measure comes to be a necessity; there is no getting rid of it. Now, the company having laid down a meter opposite the works of A. B., cannot, nay dare not, refuse the application on behalf of C. D.; the refusal would raise an outcry against tyranny and partiality. And so the manufacturing interest goes on increasingly absorbing the supply. As the manufacturers thus year by year pay more, it would be just that the rate-payers should pay less of the total burden, at least until the Water Company again increase the supplies; and this might have been accomplished by making the water-rate proportional to the time during which full pressure is kept up, which time may be easily indicated by pressure-gauges acting on clock-work.

The real source of this conflict of interests lies in the scheme of assessment by rental. The confusion can only be removed by making all pay according to the same plan. Now the manufacturers must pay by quantity, therefore we must endeavour to make the householders pay in the same manner. But all our Acts of Parliament make rental the basis of assessment, and so we must try to regulate the supply by the same standard. A householder pays so much water-duty, let us deliver him water in accordance therewith. Such appears to me to be the only way of escape out of our difficulties—difficulties which may be temporarily smoothed over by bringing in water from a new source, but which will again make their appearance when the city grows, because they are inherent in our present plan.

In order to regulate the supply nearly in accordance with these principles, I would propose to attach to the delivery-pipe in each house an apparatus by which a certain fixed rate of discharge is secured, so that if the pipe be kept constantly running a certain number of gallons shall be delivered per day. This amount being regulated amply to supply the legitimate demands of the family, and being stored in a cistern sufficiently large to accommodate the

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variable daily wants, the family will be fully satisfied; but then it will also be prevented from wasting the water, beyond the margin which is allowed for incidents. Whether this daily quantity be regulated by the rental, by the size of the house, or by the number of inmates, is a matter for consideration. Let us suppose that the rent forms the basis of adjustment; then, in accordance with the usual healthy feeling in regard to such matters, it would be expedient to reduce the allowance of water in a lower ratio than that of the rents. Some such scheme of allotment having been arranged, I should regard the quantity determined by it as the rightful allowance in virtue of the rate.

To all parties requiring more than this allowance, I would supply a delivery pipe capable of delivering the number of gallons daily according to their request, and would charge a water-rate higher in proportion. In this way the payments for water would come virtually to be regulated by the quantity which the consumer is at liberty to use, and we should make some approach to an equitable adjustment of the burden.

By such an arrangement all classes of the community would be placed nearly on the same footing. There would be no conflicting interests. Habits of economy in the use of water would be cultivated, and the present lamentable waste avoided.

In the case of a prospect of scarcity, the supply would be cut off for so many hours a-day from the whole town. All parties would be treated alike. Complaints of partiality would cease to be made, and the circumstance of one district being lower than another would fail to secure for it an undue supply.

The scheme of payment according to quantity would exercise also an important influence on the question of extended water-works. Whether these works be executed by a company or by a public trust they are virtually done on the security of the rates—that is, by the rate-payers. When the town has come, say to double its population, the water is insufficient, new works are proposed, with a new assessment to defray the cost; that is to say, the old inhabitants, after

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having provided enough, and more than enough, for their own wants, are now called upon to contribute for the new comers as well. This is a kind of injustice which can hardly be avoided on the assessment plan. But when the payment comes to be regulated by the quantity supplied, it becomes the interest of the company or trust to augment their means of supply, in the one case by subscribing new capital, in the other by new loans on the security of the additional demand; the matter would adjust itself without needing spasmodic action on the part of the community.

In all cases the action of a board of responsible trustees is to be preferred to that of an independent company; because the economy of the one, though not likely to be so great as that of the other, goes directly to benefit the virtual proprietors of the works, and therefore to produce a feeling of satisfaction; while the prosperity of that other, though fairly and legitimately earned, becomes a source of jealousy and heart-burning. So it always has been; the publican or tax-farmer has always been regarded with more aversion than those through whose authority he acts; and as, in this case of water supply, the authority is to be found among our precious selves, it is still more natural for us to cry shame upon the unhappy Water Company.

After a short discussion, it was moved by Mr Thomson, C.E., and seconded by Mr Cunningham, C.E., that a special meeting of the Society be held on the 11th instant, to consider generally the subject of water supply to the city.

Special Meeting.

Agreeably to the previous resolution, a special meeting of the Royal Scottish Society of Arts was held in the Society's Rooms, George Street, on Thursday evening, the 11th inst. —the President, David Stevenson, Esq., civil engineer, in the Chair—for the purpose of considering generally the

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question of the water supply to the city. There was a large attendance of members.

The PRESIDENT, in opening the business, stated that at the last ordinary meeting of the Society, held on the previous Monday, a paper was read by Mr SANG, C.E., on the water distribution, and after the short discussion which followed the reading of that paper, it was resolved, on the motion of Mr Thomson, that they should hold a special meeting for the purpose of hearing the opinions of the members on the subject more fully, and also in the hope that they might have some further information laid before them. The Council hoped that, as this is a deliberative assembly, and not a popular meeting, the remarks made would, as far as possible, be founded on facts, and not on anything vague or uncertain.

Mr R. W. THOMSON opened the discussion. He remarked that they were not there for the purpose of abusing either one side or the other. The Water Company had been well abused, and the Town Council had been well abused, and they might leave that branch of the subject to those out of doors who engaged in that work. The Fellows of this Society, and the citizens of Edinburgh, would see with regret any change in the supply of water to the city that would put aside the services of those who had hitherto managed it, he did not say with entire satisfaction, but well. No one under a new system of management, in any trust, could conduct the business so well as the present manager, provided he was not bound with a millstone over his neck in the shape of a six or seven per cent. dividend; and with respect to the engineer of the Water Company, he believed he was second to no hydraulic engineer in Great Britain. The cravings of a commercial society, and the demands of a community like that of Edinburgh, are not very compatible, and we would never have heard the complaints we are now hearing if it had not been for the necessity of earning a large dividend; and if instead of 6½ per cent. or 7½ per cent., the directors could manage to get on with a 4½ per cent. dividend, with the same income, they would be able to supply larger pipes, and give increased facilities for securing water.

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He expressed a hope that if the water supply was to be taken over by any public trust, the Water Company would be liberally treated. It would be unfair, after they had spent their money and run the risk in carrying out the undertaking, if they should be called upon to give it over at less than the market value. It would be bad policy and unfair to carry out some of the proposals that had been broached by those who were seeking to acquire the works for a public trust. He had no doubt Parliament would take care they were not victimised. He would say a few words on the defective supply. They had had the most positive statements, on all sides, from persons living next door to each other; some never wanted water during their whole lives, and others only had had it on rare occasions. It was very perplexing to understand how these statements could be true, but he was quite satisfied that they were susceptible of easy explanation. It could be explained by the proper study of the behaviour of water in pipes. The pipes laid down some years ago, when the supply required was less than now, could not meet the present demand. The increased supply had overtasked the pipes in the streets. Larger pipes laid into the houses would, to a certain extent only, remedy the defect, and the outdoor pipes must be made in some due proportion to the quantity of water that had to flow through. The Water Company had been laying down pipes here and there, increasing the means of supplying water, consistently with getting a good dividend, but very much of the defective supply arose from deficiencies in the size of the street pipes. They had also heard accounts of gentlemen who had visited certain houses, and found the cisterns dry and filled with cobwebs. But however perplexing that might appear, it was not to be concluded at once that there was a want of water in the pipes. It required only an extremely elementary knowledge of hydraulics to know that whatever pressure there might be in the mains, if, as it passed along, it was tapped by hundreds of small pipes, the pressure would decrease as it went on. This would be the case even when a pipe was going down hill. All these were perplexing questions, and had led people to the conclusion

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that the water supply was really deficient. It was quite obvious that within the last few months the enormous rainfall had provided the Water Company with a supply of water that would suffice for ten times the consumption that was required, and yet these complaints had not ceased. There was still in many cases a want of water in certain localities, and that would be the case until the street mains were entirely remodelled. He could not tell, from his own knowledge, to what extent that had been done, but he had no doubt that a large amount of money would be required to make street mains in accordance with the demands upon them. It had been held by the opponents of the Water Company, that the willingness of the company to lay out a quarter of a million of money upon the Moorfoot Scheme was a confession on their part that the water was deficient in quantity; but he thought it was not doing the Water Company any injustice to suppose that they were ready to lay out money upon this or any other scheme within reason which would return them 6½ per cent. In fact, for every L.25 that might be issued by the Water Company, the shareholders could procure in the open market L.34 or L.35 at the present moment. Therefore, if they were ready to lay out money, it did not follow that they were correct in supposing that the outlay would do anything more than keep up an abundant supply of water during an exceedingly hot summer, such as we had last year. The present pipes could not take more water into the town than was now done; but with regard to the relaying of the pipes, their willingness to lay out money on that part of the apparatus was naturally not quite so great, because, under the existing Acts of Parliament, and under the proposed extension of their works, with the increasing rental of Edinburgh, and the additional taxation they would be authorised to levy, they would get an addition to their revenue which would provide 6½ per cent on the L.200,000 or L.300,000 they proposed to raise; but if they took up the old pipes, they must write them off as valueless, for they would not be worth the price of old iron. It was very wrong, however, to blame a commercial company for taking care of their interests in this way. They were perfectly justified in

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hesitating to lay out more money than was sufficient to satisfy the public, and they would only be driven to lay down fresh street piping by very strong measures on the part of those who found themselves in want of water. He believed that under a public trust, where the commercial element would not enter, we should have no difficulty at all in getting the whole of our outlay so arranged that with very moderate taxation we should be able to get the street pipes renewed, and any additional supply of water obtained that might be required. But until the street pipes were put in order, and greatly increased in dimensions, and until the internal fittings of the houses were put right, there was no wisdom in going either to the Moorfoots or to St Mary's Loch for more water. Mr Thomson concluded by proposing the following motion:—"Resolved, that in the opinion of this meeting, the scheme for bringing water from St Mary's Loch has been entered into before sufficient investigations have been made as to the wants of Edinburgh, and the best means of supplying those wants."

Mr CUNNINGHAM, civil engineer, seconded the motion. He held that in all the discussions that had taken place, the first and most important point had been very much overlooked—namely, Was the present water supply insufficient, and if so, to what extent? He had read with great care all that had been said with reference to these schemes, and he thought they had arrived at no very satisfactory conclusion as to how far the present supply was insufficient. He did not deny that there were cases where there was a want of water; but then they found that some houses on a high level were well supplied, while those on a lower level had none, and the conclusion to which they must come was, that there was something wrong with the service piping. He did not think that there was any great complaint in the new town of a want of water, but he was told that in the old town there was a much greater deficiency. He did not contend that if in the old town there was a want, the new town should not bear its proportion of the expense of increasing the supply. He thought they should have full information as to the extent of the deficiency. There might be an ample supply of water, but it

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might not be equally distributed, owing to the mains being of unequal size. A better system of mains might supply the inadequacy in certain districts. He did not want to say a word as to the merits of the two schemes, but he did not think that the fact that the directors were proposing to go to Parliament for a fresh supply is any proof that the supply is deficient. The works would require three or four years for construction; and it was only common sense, and common prudence, for the directors to take proper steps to meet the demands of the population.

Mr Peters, plumber, exhibited a drawing of a large tank, to be filled by a ball-cock from the main, and in the bottom an inverted valve. He explained, that if such tanks, capable of holding one million of gallons, were erected in various localities, at a height of 150 feet, they would fill when the pressure in the mains was strong, and when it became weak, through the withdrawal of much water, the bottom valve, by opening, would keep up the supply in the locality.

Mr Leslie, C.E., who was called upon, said that a good deal had been said about the want of water last summer, as compared with the quantity supplied at present. The fact of the matter was, that last year they had only one 16-inch pipe from Colinton, and that was almost sufficient when they had the water coming from the high reservoir; but when they came to the lower reservoir, it was not enough to give the required supply, and consequently last winter another 16-inch pipe was laid, and finished in October last. Therefore it was not a deficiency of water, but the means of bringing it into town, that was at fault. He did not deny that there was a considerable want of supply of town piping, though not so much as Mr Thomson thought; very little would remedy it, and it would be done by-and-by. They could not, however, lay down this new system of piping until they saw the effect of the Colinton pipe. After the piping now under the consideration of the directors was carried out, he thought there would be no want of water at all. The great want was in the large blocks of houses in the east side of the old town, and indeed in all the

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south side of the town. The piping was altered and extended about twenty years ago to suit the increased supply and constant service, but enormous changes had taken place since that time, and the mains became too small to supply the branches; a great deal required to be done, and has from time to time been done, to meet extensions. A number of people fancied there was a great difficulty of distributing the pressure to equal levels. It is doubtless right and proper to use the water from the lower sources for supplying the lower levels of the town, and that has been attended to as far as practicable; but if they got plenty of water in the high levels, there was no fear of the lower ones. Every house should as nearly as possible have a pipe to itself to the main, or at all events each stair. So far from its being the interest of the company to have small pipes, it was very much to their disadvantage; because, although at the present time, by dint of the large quantity of water supplied—990 cubic feet per minute, which was equivalent to nine million gallons per day—they could force the water through the pipes; still, if they forced the water through the small pipes, they gave too much to the larger pipes, subjected them to undue pressure, and thus lost water.

Dr Strethill Wright said that, as a doctor and an anatomist, he had an intimate knowledge of the way in which the fluids were supplied to the human frame; and doctors all knew that when blood was required to any certain part of the body, a number of fresh pipes were laid down to supply that part. It was not necessary, as Mr Thomson proposed, to take up the old pipes, but merely to add to them as water was required. Whenever a fresh quantity of water was wanted for a new district, it was impossible that the old pipes could give the supply. The old pipes should be left to carry the water they were carrying, and fresh pipes should be laid down for increased supply. In this way a considerable amount of expense might be saved.

Mr Leslie asked if he might be allowed to read an extract of an analysis, by Professor Penny, of the South Esk or Moorfoot water.

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The PRESIDENT said he did not know whether they could venture into details as to the quality of the water; it might give rise to irrelevant discussion; but it was for the meeting to decide.

Mr R. M. SMITH wished to ask Mr Leslie, supposing the lands of the old town had been supplied last summer to the full amount required, would the ponds have been sufficient to supply the quantity?

Mr LESLIE in reply said that Edinburgh was in a different position to other towns in regard to the lowness of supply in the ponds. A great portion of the supply of water was in springs that did not depend upon the storage. The storage Edinburgh required was chiefly for the millers; the storage for the city was a light matter.

The PRESIDENT having asked if the meeting desired to hear Professor Penney's analysis, it was resolved that it should be read.

Mr LESLIE read the report. He sent four specimens of the water to Professor Penny on the 27th ult., and the analysis was dated the 8th inst. The specimens were—No. 1, South Esk at Gladhouse, below the junction of Blackburn; No. 2, South Esk at Gladhouse, above the junction of Blackburn; No. 3, Tweeddale Burn; and No. 4, Portmore Loch. The results of a detailed analysis of these samples was stated by the Professor as follows:—"From the above results it is manifest that all these waters are comparatively soft and pure. In taste and appearance they were very similar; and in chemical composition they may be viewed as practically identical. No. 1 sample has a slight yellowish tint when viewed in quantity or in deep column. All these waters are free from objectionable metallic contamination, and from all prejudicial pollution. They are perfectly wholesome, and are well adapted for dietetic and domestic purposes, and for all the uses required by a large community." Mr Leslie, continuing, said he had nothing to say against the quality of the Yarrow; he believed it to be very good water—the one as good as the other.

Mr KIRKWOOD thought that, from the muddy state in which the water sometimes came in, it must have run from

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the soil, and not from springs. With regard to the supply, there was no doubt a great scarcity; he had felt it at Dick Place, at the Grange. He should like to know the difference between the supply at the present time and 1800. Mr Ramsay could tell them what the supply was at that time. If there were a greater supply of water there would be more of it used for machines. Mr Ramsay, as a skilled engineer, could not be surpassed, and he would be the first man the new company would select, they might depend upon that.

Professor JENKIN supported the resolution. Facts were the things they really required. They heard a good many opinions, but what they wanted were facts. There were facts which he had not heard or seen stated, and which they really did require to enable them to judge whether or not the supply was sufficient. First of all, they wanted to know what quantity of water came into the town. Mr Ramsay or Mr Leslie could tell them that; but there was another thing which he feared no one could tell them, and that was, What became of the water when it was brought in? What proportion of that water really was usefully employed, and what proportion was thrown away and wasted? In order to arrive at a knowledge of this, they might compare the supply of Edinburgh with the supply of other large towns. The supply of Edinburgh per day was large compared with most towns. There was, therefore, a sort of *a priori* probability that a very large proportion of the water was wasted; and what he wished to urge upon all interested in this question was that they should collect statistics after the following fashion:—Ascertain what were the requirements of houses of a certain class; what quantity of water did houses in such and such a street, with so many inhabitants, really use. Then, if they would take the number of houses, and multiply the quantity of water actually consumed in a given class of house by the given number of houses, they would arrive at an approximation of the quantity of water really required for domestic uses. The supply for machinery being given by meter, would not offer the same difficulty. These facts ought to be ascertained

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before any scheme was brought in—what quantity was really used, and what quantity was wasted. The quantity wasted was, he was sure, enormous. They had heard from Mr Thomson and from Mr Leslie that the supply in the different houses depended upon the pressure of the water in the pipes at those houses. What the supply depended upon was not the level, but the pressure of water in the main at any particular house. He should like, therefore, to see statistics gathered as to what the actual pressure was in the mains in the different parts of the town; what variations took place during the day, during the night, and on different days of the week. If they had these statistics it would be perfectly futile for any man to come forward and say that he did not receive water on a certain day, if the pressure was proved to have been there; the fault must in such a case have been in the service pipes; and, on the other hand, if the pressure was really wanting, it would not do for the company to say it was the fault of the service pipes. As to trusting to particular individuals who came forward—one man saying that he had water, and another saying that he had none—that proved nothing, because they could not say whether the want was due to the main or to the service pipes. He could not help being struck, as an engineer, at the comparison between the tests in one branch of engineering and the tests in another. In all questions of the flow of electricity they had tests that enabled them to ascertain what became of the currents that flowed through the wires. Now, they had nothing equivalent to this in hydraulics—they had no set of apparatus by which even to test the amount of water passing through the mains at different points. The system of hydraulic testing had never been fully carried out, and that was what was wanted.

Mr R. M. Smith said they might assume that they would have sufficient pressure if they had sufficient water, but if they had not sufficient duration of that pressure then they had not sufficient water to fill the cisterns in all localities. If the water was cut off, that was sufficient indication that there was a want of water. He had found this suspension of pressure at Bellevue Crescent.

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Mr Ramsay, the manager of the Water Company, next addressed the meeting. He began by expressing his thanks to the gentlemen who had spoken for the kind things which they had said of him and of Mr Leslie. It was extremely kind of them to make these remarks, and he was very much obliged to them. Mr Thomson had alluded to the transfer of the water to a trust. He did not know that that was a matter for this Society. It was certainly not a matter connected with hydraulic science; but he might mention that, notwithstanding all this fuss that had been made about a trust, there were clauses in the existing Acts of Parliament under which the public of Edinburgh might at any time during the past twenty-two years have acquired the Water Company's works, and he had never heard any director of the Water Company, or any person connected with the Company, attempting to interpose the least difficulty in turning them over to a trust. He was quite sure that whenever that trust was applied for under the Act of Parliament, no resistance would be made, or could be made to it, for there was no possibility of resisting it. He might say, however, that there was no other way by which the works could be acquired. The Town Council had no power to buy, and the Water Company had no power to sell, otherwise than in the manner prescribed by the Act of Parliament. As to the question with regard to larger pipes, the Water Company had been for the last two or three years engaged, in a larger or smaller way, in extending their mains. The directors, although they had no statutory authority to do so, had laid a 16-inch main between Morningside and the reservoir at Torduff—a distance of four miles; and they had extended large branches down the Links, and along the Morningside ridge to Newington. They made these and other extensions without statutory authority, to meet the wants of the community, at a cost of something probably not very far short of L.20,000. Until that main was laid down, by which an immense additional quantity of water has been brought into the town, it was quite impossible to see what alterations were necessary on the town piping. These two 16-inch pipes, which have been laid along the

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line to which I have referred, would carry 900 cubic feet water per minute; and then they had 250 odd feet from the Crawley pipe, and 60 more between the Swanston and Comiston pipes—making altogether in these five mains 1200 feet per minute of carrying capacity. At this moment the delivery of water in Edinburgh is 992 cubic feet per minute.

The CHAIRMAN—The new Crosswood water comes through the Colinton main?

Mr RAMSAY said it did. Now, in regard to street pipes, in so far as they were available, it would be a great error to take them up. The pipes were as good as when they were laid down, and Mr Leslie and himself had orders from the directors to lay new pipes wherever necessary. The only delay in the matter was, that they were waiting to see what would be the effect of making one large extension before they proceeded with the next. They had a stock of pipes of a large size in their yard at present, and these pipes would all have been laid in December had they not been interrupted by the weather. He was unwilling to begin during the short day, but when they did begin they would go on and lay these pipes as fast as possible as they might be required. As to the distribution, everybody must know that there were three essential conditions in connection with it. The first was, there must be a sufficient quantity of water. No mode of arranging the pipes would help them unless they had water to put in them. Having water, the next thing was that the mains must be of sufficient capacity to convey it; and the third, that people who wanted water into their dwelling-houses must provide proper means of taking it in. The latter difficulty prevailed to a most incredible extent in Edinburgh. He had done everything in his power to throw light on the subject, but he had been met by a class of people who had been trying to educate people into the waste of water, alleging that they could not waste too much of it by any means—that the water which went down the water-closets, or into the common sewer, all operated beneficially. He had before tried to show that that was a mistake. If they wanted to flush a water-closet or a com-

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mon sewer, that was not to be done by turning on a small pipe and leaving the water to run, for unless the inclination in the drain was very great, the water in that case merely ran over the solid matter. What was wanted was to flush it by letting down a rush of water suddenly, for which a small quantity, if only let off in a body, is sufficient; and every one should know that the effect of keeping up the handle of a water-closet is to fill the house with poisonous air. With regard to the quantity of water brought into town, he said that in 1819, before the incorporation of the company, when the supply was in the hands of the Town Council, the quantity brought in never could exceed 60 cubic feet per minute, and was frequently as low as 12, and always necessarily at the lowest point at seasons of the year when it was most required in town. When the company brought in the Crawley water about 1823, it provided the town on the whole pretty satisfactorily up till 1842, when there was a drought, which many gentlemen in the room may well remember, and certainly one of the most severe droughts that ever occurred in his day. Up to that time the delivery was about 250 cubic feet per minute, and the population in Edinburgh, Leith, and Portobello was 166,878, the supply being thus equal to 13·41 gallons per head per day. In 1843 the company went to Parliament and got powers to bring in more water, and by 1849 the quantity was increased from 250 feet from the former sources to 460 feet; and the population had then increased to 185,000. The supply of water gave 21¼ gallons per head per day. In 1856 the quantity had risen to 560 feet, and the population had increased to 199,782. The delivery was thus about 25·17 gallons per head per day. In 1863 the quantity brought in was 731·8, and the population 208,647, the supply now being $31\frac{8}{10}$ per head per day. The delivery at this moment was 991·96—or say 992; and putting the population at 220,000, it gave nearly 40 gallons per head per day for that population. The company, however, had not that number of people in their books; but whether in their books or no, the company furnished them with water. A great quantity of water was in this and other ways distributed gratuitously. They had

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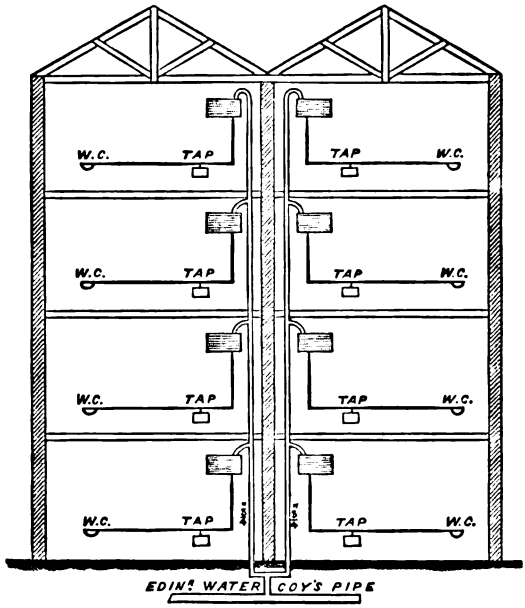
public wells where the poor people got their water, and they supplied a number of charitable institutions, including the Royal Infirmary, gratuitously. They had 38,000 families upon their books, representing 190,000 people—he was taking the ordinary average of five persons to a family—so that, in addition to the 190,000 persons who paid for the water, 30,000 were supplied who paid nothing. Mr Ramsay proceeded to illustrate his remarks, regarding the objectionable mode of supplying water to common-stair houses, by means of numerous diagrams, all of which represent existing tenements, but of which only the following four are here reproduced.

The diagram (No. 1) represents a tenement occupied by

No. 1.—Eight Tenants.



eight families. It represents a vast number of a good class of common stair tenements recently built, and occupied by tenants paying rents from L.20 to L.40. At the bottom of the diagram is the Water Company's main pipe, from which a

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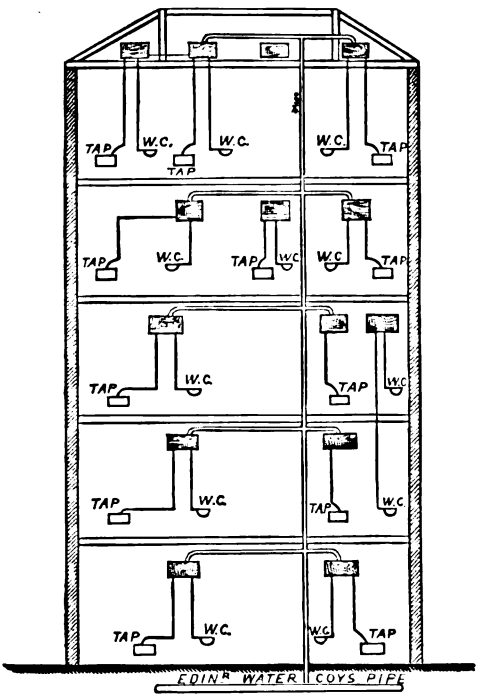
¾-inch supply-pipe is taken. That ¾-inch pipe, represented in the diagram by double lines, is the supply pipe for the tenement. It branches off to the right and left into two pipes, by which the water is conveyed to cisterns in the roof. On each of the four floors in succession, branch pipes, leading direct from the supply pipe, are taken into the cisterns of each house. There are thus two ascending sup-

No. 2.—Twelve Tenants.



ply pipes, each with four ¾-inch branches, the whole water for which passes through the one ¾-inch pipe connected with the company's main. In tenements so fitted up, the tenants in the lower part of the house command the whole supply, and a faulty ball-cock, leaky taps, or the water in the water-closet running to waste, unavoidably deprives the whole of the other tenants of their share of the supply. Where the tenants are more numerous than the eight re-

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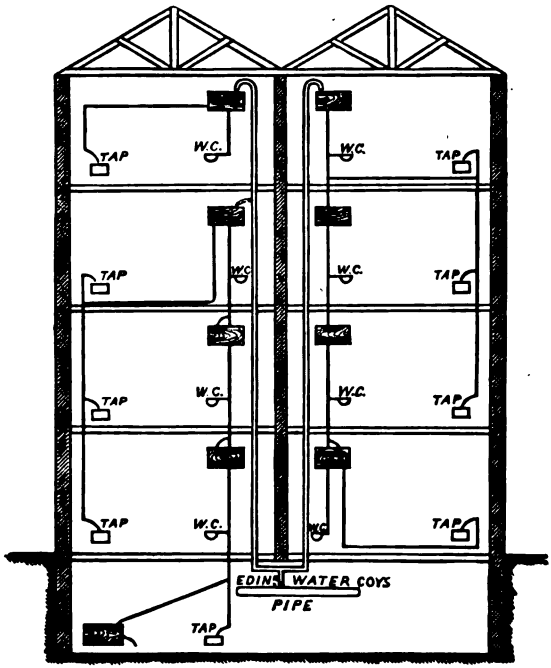
presented in this diagram, the evil is presented in a form, aggravated according to the increase in the number of the occupants.

The diagram (No. 2) represents the same evil in a different form. Here again there is a ¾-inch supply pipe, with branches taken off right and left as it ascends, for the supply of the five

No. 3.—Eleven Tenants.



floors of the tenement, occupied by twelve separate families. In this tenement, as in the other, the water is commanded by those lowest down, and any derangement of the ball-cock, water-closet, or taps, will in like manner deprive the others of water.

The next diagram (No. 3) represents a different mode of supply. There is here also a ¾-inch connection with the company's main. This again is branched off for the supply of two sides of the tenement. On the right hand side the supply pipe is carried direct to a cistern in the roof without

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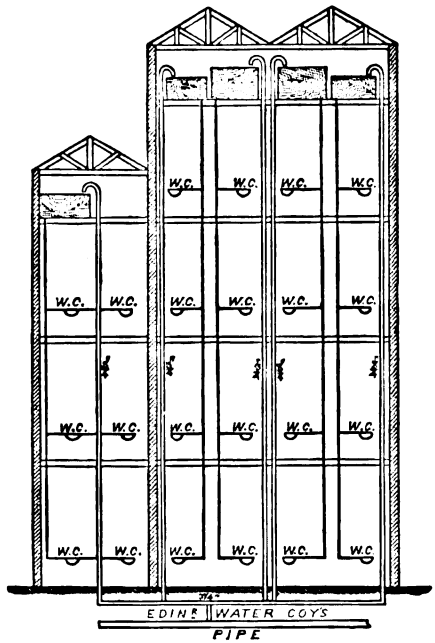
intermediate branches, and the four floors on this side of the tenement are supplied by a pipe descending from that cistern through the successive floors—the whole supply in this case coming from the roof, to which in the first instance it has been sent. The same difficulties here occur

No. 4.—Twenty-two Tenants.



as in Nos. 1 and 2, only in an inverted form, and any disorder in the apparatus, such as has been already described, will produce the like result.

The left hand side of this tenement is supplied in a form which I shall term *composite*, the supply pipe being carried to a cistern in the roof, but with a branch taken off for the supply of the three floors, and also to premises beneath the level of the street.

The next diagram (No. 4) is a master-stroke of absurdity. From the company's main there is one $\frac{3}{4}$-inch branch pipe at right angles to which it is extended on both sides. On the

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one side are three ¾-inch supply pipes; on the other side, two ¾-inch supply pipes, all deriving their supply of water from the one ¾-inch branch on the company's main. There are twenty-two families in this tenement, and this one branch pipe of ¾ of an inch is supposed to be sufficient to supply five pipes of that size. It is a four-story tenement, except on the left hand side, which consists of three stories only. The whole of the water passing through these five ¾-inch supply pipes, supplied by the one ¾-inch pipe from the company's main, goes direct to cisterns in the roof, from which it is drawn off for the supply of the floors beneath. The left hand side of the tenement being only three stories instead of four stories, as on that of the right hand, and supplied from the same branch on the main, has the advantage of being a story lower, and thus commands the whole water furnished to the tenement. Till the cistern there is filled, or while water is being drawn from it, either for use or from leaky apparatus, not a drop can pass into the cisterns of its taller neighbours. Here, then, are twenty-two water-closets for the use of as many families, with double that number of drawing-off taps, and a constant supply of water to each family being, under such circumstances, a physical impossibility, one cannot help asking whether the author of that arrangement intended that they should be properly or satisfactorily supplied.

Reverting for a moment to diagram No. 1, it may be remarked here that in place of one ¾-inch supply pipe, branched off into two pipes, also of that size, a separate pipe connected with the company's main, for each of the eight houses, or, at all events, for each of the four floors, would have afforded a remedy; even a separate connection with the company's main for each side of the tenement would, although imperfect, have been greatly preferable to the mode which has been adopted. But when these diagrams are examined, and when it is considered that precisely the same arrangement occurs in tenements occupied by thirty or forty families, each of whom, appealing to empty cisterns, clamorously demand a full and constant supply of water, and affect to hold the Water Company responsible for the want, the

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unreasonableness of the demand, and the impossibility of complying with it, become sufficiently apparent.

The CHAIRMAN asked Mr Ramsay if he had formed any estimate of the population supplied in this faulty manner.

Mr RAMSAY said that in one of the places he had described, there were no less than fifty-one families, all of whom were supplied from one ¾-inch pipe. In common stairs, of the best description, there are generally from four to eight tenants. Indeed, there were seldom fewer than eight, and some of them rented at from L.30 to L.40. A vast number of these houses had been erected by builders,—who were great economists—he did not mean of water—who, in place of being at the expense of getting proper pipes and apparatus to supply each floor, would not even be at the expense of a second joining to supply two sides of a stair. Mr Ramsay went on to say that in 1842 the delivery was 249·5 feet, and that it was now 992, being more than 250 per cent. of an increase on the water supply, while the population had only increased to 24·10 per cent. They had thus not only kept pace with the increase in the population, but had exceeded it tenfold. With that great quantity of water, it was natural to ask how there should be any difficulty. He frankly confessed that there were difficulties with regard to the mains, but the directors had given instructions to have these difficulties remedied, and it was in the course of being done. But no matter to what extent they altered their mains, so long as arrangements of the kind he had described were continued within the houses, a sufficient supply of water was a physical impossibility.

The CHAIRMAN asked if the company could not interfere with these arrangements.

Mr RAMSAY said they could not. They tried when they were last in Parliament to get clauses put into their bill which would have furnished a complete remedy; but they were met with opposition from the Town Council, and were forced to withdraw these clauses. Had they been able to carry them, the people would have got an abundant supply of water, and the company at the same time would have been able, by the prevention of waste, to render unnecessary

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the proposed expenditure of several hundreds of thousand pounds to bring in more water. Mr Ramsay then passed on to notice the consumption of other towns. His attention had at one time been especially called to Oxford, and he had taken the opportunity to run up to that city. He found the supply there was 110 gallons per head per day, and the authorities at the water-works told him that they had the water for pumping, and it did not cost much, and they therefore allowed the people to do with it what they liked. But in other towns, where the water was always abundant, under proper regulations of the kind he had alluded to, and where they had proper apparatus, he found the quantity varying from 14 to 20 gallons per head per day, and that this was abundant. A case had recently been tried in Edinburgh, in which there were a number of witnesses examined—one from Manchester, where 650,000 people were supplied—who stated that 20 gallons per head per day was there consumed, including 6 gallons for trading purposes, reducing the quantity for domestic use to that large city to 14 gallons per head per day. In England they found the quantity scarcely ever beyond 20 gallons. He could mention numerous towns he had visited. The lowest quantity delivered was 13 gallons per head for the minimum, and the highest 21 gallons for the maximum, and everybody was abundantly supplied and satisfied—not a single complaint. Here were they delivering in Edinburgh at this moment upwards of 40 gallons per head! The quantity was astonishing. Any gentleman might see there was nothing like that quantity consumed by his family. Fourteen per cent. of the supply was sold for trading and manufacturing purposes, but the remainder of the 40 gallons was available for domestic uses. Surely there could, or at least should, be no want of water. But some gentlemen said, that the fact that the company were proposing to go to Parliament to bring in water from the Moorfoot implied a scarcity of water. He for one had never admitted the scarcity of water; there was an abundant supply of water, provided there were proper regulations for its distribution. But the choice was whether the company should go to Parliament to

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bring in more water, and allow the people to go on wasting it; or, whether they should take their chance of going through an expensive Parliamentary contest, in order to obtain power to secure that such apparatus only should be employed as would render it possible that a full and constant supply might be furnished to each tenant, and, at the same time, confine waste within reasonable limits. The directors knew there was abundant water if people did not waste it, and if proper means were adopted for its distribution. But as long as they wasted it, and as long as the means to render it available within their houses was imperfect, there would always be complaints, no matter what supply was brought in. Suppose they brought in the German Ocean, there are many tenements which, with the present house arrangements, they could not supply, and never would be able to supply satisfactorily, till these arrangements were changed. There was a popular outcry for more water. He had asked people who took a lead in raising that cry, "Will you tell me how much water you want?" No one had specifically answered the question. The answer was, "We want as much as we can get," which meant as much as they could run off or waste. But the fact was, this demand was made not to meet the wants of the general inhabitants, but the wants of a certain class of houses. The Water Company proposed to expend L.200,000, and L.400,000 was spoken of as the cost of the scheme of the City Corporation. This L.200,000 or L.400,000, whichever it might be, fell on the general community with the incidence of a public tax. It was the business of house proprietors to have fitted up their property efficiently, and they had no right to ask the public to lay out L.400,000 to bring in water from St Mary's Loch, or even the L.200,000 for a supply from Moorfoot, merely to exempt them from an outlay which they ought to have provided at their own cost. Such houses were in the New and Old Towns both. Forty gallons per head per day was an abundant supply, supposing they took means to enable them to get it. They wanted some alterations in their mains; they were not

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very extensive, but whatever was required, it should be done —it should be fully met.

Dr STRETHILL WRIGHT—Can these mains be supplemented, or must they be renewed?

Mr LESLIE—Sometimes the one and sometimes the other.

Mr RAMSAY next proceeded to notice a complaint about scarcity of water which had been made by the occupier of stables in Regent Terrace Lane. There were thirty stalls, he said, in his stables, and there were nine more stables in the place, and four families in the lane, and the whole premises of these parties were supplied by a ¾-inch pipe. On hearing of that complaint, he sent an officer immediately to apply the test which had been so properly suggested by Mr Thomson and Professor Jenkin, and he found that the pressure on the main to which that service-pipe was attached amounted to 75 vertical feet, enough to carry it over the highest chimney in the neighbourhood; and yet these people could not obtain their necessary supply of water, and there would be similar complaints continually until the control of the apparatus was got into the hands of those who supplied the water.

With regard to the want of water last summer, some people raised a cry that the reservoirs were empty. A deputation from an important public body waited upon him, and said they wanted to know about their arrangements for measuring the water in the country. He showed them on the Ordnance maps where the water was measured, and said that if they had any curiosity to see the works and measuring apparatus he would be very glad to take them out. They did not accept the offer. After some explanations had been made, it occurred to him that his company would not be acceptable, and he then offered to give them an order to admit them to the works, and to show them everything. They at once accepted this; and he learned that half an hour after they had left his office they were on their way to the works to measure the water. They refused to take him with them, and he was prepared to show that they were in error in their measurement. Had they taken him they could have tested everything in his presence;

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but they measured the water without him, and said that the reservoir had not more than a fortnight's or three weeks' supply. He did not know what reservoir they referred to, but the Glencorse reservoir had sufficient water to keep up a supply probably to New-Year's-Day. But supposing that they meant the reservoirs for the town supply had failed, they had upwards of 600 cubic feet of water from springs that nobody can see. It was brought into town from springs by underground pipes, and never saw the light of day until it was delivered in town. That was a most important condition; for while other towns depending upon reservoirs suffered immensely last summer, they never suffered, notwithstanding that about the time of this visit they ventured to do a thing which, although it caused Mr Leslie and himself great uneasiness, showed how confident they were of their ability to maintain the supply. A necessary piece of work had to be done which required all the water west of the Black Springs to be turned off into the Compensation Pond. It was turned off from the Monday morning until the Tuesday of the following week. The water taken off amounted to 460 cubic feet per minute. They did that in the face of one of the most intense droughts ever experienced in this country, and it never interrupted their supply for one hour during the whole of that extraordinary season. But the cry continued, and, with the kind of house apparatus to which he had referred, would continue for evermore, in spite of everything that could be done. As to the deficient supply of water, he asked if every one suffered alike. Nobody would say that the great bulk of the inhabitants had wanted water, or had wanted it for an hour. But if people next door to them, living on the same level, did not get it, the natural conclusion was that there must be something wrong with their apparatus; and in such houses there never could be an abundant supply under the system he had explained to them. The first question then was, whether the want of water was general, or whether the want was only in particular districts. If it was neither general nor applicable to any special locality, but only in houses fitted up in an objectionable manner, the fault and remedy lay with the

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proprietors and not with the Water Company. Mr Ramsay concluded by saying that he wished to put himself right about a matter which had been much talked about. In 1863 he wrote a paper which he read before the Society of Arts, in which, after stating various particulars as to the consumption of water, the following passage occurs:—

"In the face of this large and increasing consumption, it should not seem surprising that the directors of the Water Company, while proposing to augment the supply, should be desirous at the same time to place some restrictions on excessive and useless waste.

"Mr Leslie was instructed to make the necessary survey, and to prepare plans for bringing in the springs on the lands of Crosswood and adjoining district on the western boundary of the county of Edinburgh. Indeed, there was little room for choice in the matter. The Water of Leith and the North and South Esk were either already appropriated, or in such a state of pollution from paper-mills and other manufactories as to render them totally unfit for domestic use. The short distance to which the Crosswood springs had to be conveyed to the aqueduct at Rashiedean, which had been constructed with a view to their being brought to Edinburgh by that line, was an important recommendation, and left no room for doubt as to that branch of the scheme."

This statement about the South Esk had given rise to remarks which he wished to meet. At that time Mr Leslie heard that the Town Council had employed an eminent gentleman, the late Mr Benjamin Blyth, to make a survey and see whether a supply of water could be got in the neighbourhood of Edinburgh. Mr Blyth examined this very Moorfoot district, and reported decidedly in its favour to the Town Council, and presented at the same time a very satisfactory analysis of the water of that district from Professor Playfair. People said that he (Mr Ramsay) had condemned this water; but at that time he had no idea of obtaining water by collecting the rainfall of a large area, or otherwise than from a river or lake, or from springs of a sufficient aggregate, nor had such a thing occurred to Mr

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Leslie. He knew the ground well up to the village of Temple, but he had never been beyond that village. At this time Mr Leslie went out and examined the ground, with the view to meet any question that might arise connected with the anticipated action of the Town Council. He came to the same conclusion that he (Mr Ramsay) did, with this additional difficulty, that not only was the water impure, but that any supply to be there obtained was too low down to be available. He knew that the water was mossy—that it came off peaty ground. Three years afterwards Mr Leslie and himself were under instructions to explore the whole country to see where water could be got. At this time he (Mr Ramsay) thought a supply could be got from the Cobbinshaw Reservoir, but on getting it analysed it was found to be unsuitable. Mr Leslie then examined the sources of the Almond, the Line, and the Moorfoot and Heriot grounds, and fixed on the Moorfoot,—the identical site Mr Blyth had recommended to the Town Council in 1863. In the meantime Mr Bouch had also been making inquiries on the same subject, and in 1864 had hit on the very same ground, only taking in a larger area than that proposed by Mr Leslie. Still more remarkable, a gentleman whom he saw in that room, Mr Allan Stewart, had also been making similar inquiries, and had fixed on the same locality. There never was such a corroboration of testimony in favour of any scheme as was here furnished by these four gentlemen, all pursuing the same object,—all acting independently of, and without the knowledge of each other,—all of them thoroughly qualified to give an authoritative opinion on the question in which they were thus employed. He had said there was mossy water, but he had never been higher up than Temple; and Mr Leslie also found that peaty water was there, but due to one burn only, which admitted of being separated and given off at a lower level for compensation. Mr Ramsay thanked the Society for the kind hearing they had given him.

Mr Mackenzie asked what method was adopted to ascertain what quantities of water were brought into the town.

Mr Ramsay explained that there were cisterns at the re-

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servoirs, by means of which the water supply was calculated with the utmost accuracy.

Mr R. M. SMITH asked if Mr Ramsay would give the meeting any information as to the practice of the Water Company of occasionally cutting off the supply of water in particular districts at particular times of the day.

Mr RAMSAY said the water was never taken off except when pipes were being laid, or when they were under repair. So particular had he been about this, that instead of allowing each officer to have the command of his own district, he had put the regulation of the supply into the hands of one man, and any officer who interfered with the distribution as so regulated, with the view of getting a larger supply to his own district, would be immediately discharged.

Mr GOWANS, architect, asked Mr Ramsay to explain the scarcity of water at the fire at Newington, the other night.

Mr RAMSAY said the people in Edinburgh had an unfortunate taste for doing absurd things. They had a particular description of fire-cock which had become obsolete almost everywhere but here,—namely, the old-fashioned fire-cock moved by a lever handle, which was merely that most objectionable of all forms of cock, known as the "ground cock," on a large scale. When the fire occurred, the firemen arrived without their engine, and in endeavouring to open the fire-cock the handle broke, and thus stopped all access to the water. The crowd got very impatient meantime, and the hose were taken down to another fire-cock. The engines still had not arrived, and two sets of hose were put on to one cock. There would have been plenty of water for one set of hose, but there was not enough for two. When, at last, two engines came, this supply of water was turned into the cisterns of the engines, which being set to work there was as much water as could be used. He was not sure, but he thought this was the first case for a number of years in which there had been occasion to use the fire-engine at all, there having always been sufficient pressure in the main.

Mr GOWANS supported the motion. He had held property for twenty years, the rents of which ranged from L.12 to

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L.100, and he never had a single complaint of want of water.

Professor JENKIN said he thought he could explain where the water went. When he went into his house a few months ago, he found all the ball-cocks out of order, and sufficient water escaping to have supplied twenty-four houses.

After some remarks from Mr THOMSON,

Mr SANG said, that in taking the responsibility of introducing this discussion to the Society, he had endeavoured to make his remarks as general as possible, feeling that there is a great want of information on the subject. He was perfectly satisfied with the explanations given by Mr Ramsay as to the cause of deficient supply in many houses, but would observe that service pipes which had been sufficient when there was full pressure in the mains, may have come to be deficient by the lessening of that pressure, caused by a greater demand. He cordially supported Mr Thomson's motion.

The CHAIRMAN asked if the resolution was agreed to.

Councillor ROWATT said he hoped all the parties present would not be held as having adopted it. He had taken notes of many things that had been said, and would have replied but for the lateness of the hour. Many remarks had been made which admitted of a complete answer. He declined to make any remarks further than this, that if they waited till they ascertained what quantity of water would be required to supply the city they would never proceed with this or any other scheme. Even accepting Mr Ramsay's statements as correct, he held that we wanted a great deal more water. He had been through the closes in the High Street and Canongate with Dr Littlejohn, and he declared that unless they could flush the closes almost daily, or three times a week, they would never have a healthy city. In Paris, and also in Oxford, Tiverton, Truro, and other English towns, there were streams of water running down the streets, and why should there not be the same here? After what had already been said, he despaired of convincing any man that there was a want of water.

Mr R. W. THOMSON said that, when he lived in Paris, he

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found that a cistern for a house for supplying eleven people contained fifteen gallons, and he found from the water carrier that that water was sufficient generally for the whole family's consumption. When a bath was required, of course the water used was brought in separately. That was giving about a gallon and a quarter per head per day of water to the people, and at the same time the water was running down the gutters in the manner that had been described.

The motion was then put to the meeting and agreed to, and the meeting adjourned.

Description of an Improved Variation Instrument for observing directly the Variation of the Magnetic Needle. By E. Elmslie Sang, C.E., Edinburgh.*

In the construction of instruments for observing the magnetic direction, there are two things to be attended to—first, we have to insure that the points of observation on the needle be in line with its magnetic axis; and second, we have to transfer that direction accurately to some distant object.

In order to correct any error in the collimation of the marks on the needle, I place a small ivory reference sphere at each end, and make an arrangement for reversing the needle face for face.

The transference of the direction of the short line passing along the needle to distant objects is usually intrusted to the instrument maker, who endeavours to place the zero line of the magnetic readings exactly under the telescope when horizontal. This arrangement is seen on most theodolites. In it the error of collimation is constant for the same instrument, but there is no means for ascertaining the amount of error.

In Dollond's Variation Transit, the ends of the needle are observed by placing on the object-glass of the telescope a

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* Read before the Society on 12th April 1869, and awarded the Society's Medal and Plate, value ten sovereigns.

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lens having its focal distance equal to the distance of these ends. The removal of this lens allows distant objects to be seen, and thus refers the direction of the needle to those objects.

In the contrivance which I have the pleasure of bringing before the Society, this difficulty has been entirely removed. The peculiar character of the crystal pointer, invented by my father, and described by him to the Society some time ago, enables the observer to examine near or distant objects with equal facility, and without any change in the arrangement. I have made use of this property of the pointer in the construction of the instrument before you.

The instrument consists of a box a little longer than the magnet, with a steel stile in the bottom on which the magnet is made to work; the box is glazed on the top at both ends, for the purpose of allowing the position of the ends of the magnet to be observed; at one end there is an arrangement for introducing and removing the magnet as may be required. On the middle of the top of the box are three conical points, which serve to keep a small altitude and azimuth circle, provided with a crystal pointer in a definite position.

When using the instrument, the box must be placed horizontally and roughly in the direction of the magnetic line. The theodolite is then adjusted, and the bearings of both ends of the needle observed. The magnet is now removed and reversed face for face, the observations again repeated, so that should the ivory balls be out of line with the magnetic axis, the mean of the readings will give the true magnetic bearing, which bearing can easily be transferred to a distant object, or compared with the true meridian previously found.

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Altered Relations of British and Foreign Industries and Manufactures: Address by the President, DAVID STEVENSON, Esq., F.R.S.E., M. Inst. C.E., *concluding the Session of* 1868–69, *delivered at the General Meeting of the Society held on 8th November* 1869.

IN 1852 you were pleased to nominate me as President of the Royal Scottish Society of Arts, and having last year selected me a second time to occupy the same position, I should be wanting in gratitude did I omit, on this the last evening of holding office, to offer you my most sincere thanks for the double share of honour and confidence which you have thus been pleased to repose in me—an honour and a confidence, let me add, which encourage me to bespeak your indulgence in selecting for my closing address a subject not altogether new to you. Its importance must be my apology.

Relations of our own and Foreign Countries as regards Arts and Manufactures.

In the period that has elapsed since I last retired from this chair, not only have mighty strides been made in all departments of art and science, both at home and abroad, but events, political and social, have occurred in rapid succession, so that the whole national aspect of our country is materially altered; and in no respect, perhaps, is the change which a few years have brought about more apparent than in the altered relations which exist between our own and foreign

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countries in the all-important subject of arts and manufactures. This alteration, as you are aware, has been very generally regarded as favourable to foreigners and detrimental to ourselves, and has resulted in directing general attention to the subject of education, which is undeniably *the question* of the present day—the theme of our politicians—the study of the thoughtful class of practical men, to whose hands chiefly are confided the interests of the working classes of our country; and I may add, the difficulty of all who have attempted legislationbearing on the social condition of the people.

The Royal Scottish Society of Arts has not failed in encouraging the consideration of this most important subject, and some of you may think that you have had enough of it in the many and excellent addresses to which you have listened in this room; but it is just because you have attested your acknowledgment of its importance that I am emboldened, on the present occasion, to ask you to listen for a short time to some remarks regarding what appears to me to be the true international position of our arts and manufactures, and the causes which operate unfavourably to their full, or at least their advantageous development, and perhaps you will be all the more content to listen, as the observations I have to offer are, I am well aware, not in accordance with views which have been pretty widely expressed in this country.

Demands for Improved Education.

These views, whatever may be the exact opinions of their supporters, seem to assume the form of two distinct propositions—*First*, That the manufacturing skill of the working classes of this country is on the decline; and, *secondly*, That this is due to the want of technical

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education. In short, a cry has been raised that all nations are beating us, and this cry at the time of the French Exhibition of 1867 almost assumed the character and proportions of a national panic, and resulted, as you are aware, in appointing Government commissioners of inquiry, who took abundance of evidence and made elaborate reports—in sending deputations to ascertain the state of foreign education and manufactures—and in holding educational conferences in all parts of the kingdom. This same cry, I may add, forms the text of an elaborate and ably written volume on Systematic Technical Education, by Mr Scott Russell, in which he deplores that "the uneducated English folk are suffering great "misfortune in their trade, commerce, and manufactures, "as well as in their social, moral, and intellectual condi- "tion, through having been neglected and allowed to fall "behind other nations better cared for by the men whose "duty it was to lead as well as to govern the people," and who comes to the startling conclusion that the skill of our mechanicians has so declined, and the workmanship of our foreign neighbours has so increased in excellence, that nothing can save our commerce but the immediate establishment of a metropolitan technical university, with a teaching staff of one hundred and one professors; fifteen local technical colleges, with twenty-five professors in each; one thousand local trade schools, with from six to eighteen teachers, requiring an annual Parliamentary grant of one million in the first instance, and increasing till the annual vote of England for education has reached five millions per annum, the whole of this gigantic system to be under a Government minister of public education.*

* Systematic Technical Education for the English People. London, 1869.

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The select committee on scientific instruction, appointed by Parliament in 1868, report that "all the "witnesses examined before them desire similar ad- "vantages of education for this country to those "enjoyed by foreign nations, and are satisfied that "*nothing more* is required, and nothing less will suffice, "in order that we may retain the position which we "now hold in the van of all industrial nations." The committee do not, it is obvious, take so extreme a view as Mr Russell, but still they hold with him that education, and education *alone*, is the *panacea* for all our commercial evils.*

Effect of International Exhibitions.

Now, no one will deny that at the first great International Exhibition, inaugurated by the late Prince Albert in 1851, British manufactures held a pre-eminence, both as regards quality of workmanship and wide-spread monopoly, which subsequent international exhibitions have demonstrated, cannot now, atleast in so many departments, be claimed for them; and on this admitted fact as a foundation, the whole of our national agitation on the subject of technical education has been reared. Nor does it appear that this national jealousy is peculiar to ourselves, for it may be stated, in passing, that the French in 1863 appointed a commission on technical instruction, to examine the institutions of our own and of other countries, in consequence of the Minister of Agriculture, Commerce, and Public Works in the French Cabinet having called attention to "the "great progress made by other countries in arts and

* Report of Select Committee appointed to inquire into the Provisions for giving Instruction in Theoretical and Applied Science to the Industrial Classes. 1868.

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" manufactures, compared with that made by France," * so that we have not been the first to raise the cry of the supposed national decline of manufacturing skill.

We must, indeed, admit that we no longer hold our distinctive pre-eminence in workmanship and monopoly as a nation in international exhibitions, but we must determine how far this change is due to the deteriorated work of our artisans, or to an advance in the mechanical skill of our foreign neighbours. That is really the alternative question with which we have to deal, and before we can intelligently attempt to legislate on the matter, that question must be duly considered, and conclusively answered.

Now, to go back to the Exhibition of 1851, we then, as already stated, had confessedly great national pre-eminence accorded to us. But the system of transit by steam and railways brought to our shores, attracted by this the earliest of international exhibitions, the thinking classes of all parts of the world, who came to see and to judge for themselves, and who went away, I have no doubt, satisfied of the superiority of British workmen in most departments of manufacture, and since 1851 foreigners have undoubtedly made good use of their time. They have cultivated with success the branches of manufacture in which *we* excelled and *they* were deficient, and the result is just what might have been expected, being the natural consequence of intelligent manufacturers and skilful workmen applying their minds and hands to attain perfection in their own department of business, after seeing with their own eyes that superior work was done by their neighbours. This improvement in foreign manufactures seems a necessary

* Commission on Technical Instruction appointed by Imperial decree, 22d June 1863. London, 1868.

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result of international exhibitions, and yet we find some of the English jurors of the last French Exhibition, who were consulted by the Commission of Inquiry, evidently expressing surprise at this natural state of matters, and reporting that they are sorry to say that, although we may be still unsurpassed in many of our productions, we no longer hold that pre-eminence which was accorded to us in 1851. Now, it would, I think, be overstraining to an enormous extent, even the old admitted British pre-eminence and the circumstances which may have led to it, to expect that such people as the French and the Americans are incapable of rising to equal excellence with ourselves. There is nothing, surely, inherent in British blood to justify such a conclusion, and therefore we need not be surprised if the information afforded by international exhibitions, and the facilities for interchange of visits and opinions among foreign countries, have led to the undeniable result that the skill which was once a distinguishing feature of British manufactures is now shared by other nations.

Imitation of Improvement natural to every Country.

Allow me, in explanation of these views, and in illustration of what I may term the *imitative qualities* of a people, to refer to certain facts within my own knowledge and observation. They happen to prove that British manufacturers can benefit by foreign example, and they will, I think, also show that progress in any scientific or practical department of trade in no way necessarily infers a falling off in the talent or the skill of the nations from whom the lesson of improvement has been derived. The facts to which I refer are instances in which our country has profited

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by the excellent example of foreigners; and, first, I notice steam navigation.

In visiting America in 1837, for the purpose of informing myself on the subject of American engineering, I was at once struck, as I think any engineer would have been, with the advanced state of steam navigation in the United States, and determined to investigate the subject with great care. Railways at that period were not at all in general use, and America, with its enormous rivers and lakes, was just the country where it might be expected that steam navigation would be carried to great perfection, and so it was. By adopting fine lines for the models of their vessels, and using engines of high power and long stroke, I found that their swift steamers easily attained a speed of over 16½ miles per hour. Now, at that time, I must remind you that British steamers were invariably built with bluff bows, being what were termed sea-going ships; that their engines were under deck, and had short strokes; and that the speed attained was, even in the best vessels, not much more than half of that regularly run by the Hudson and New River boats.

In 1838, when I published the result of my observations, giving the *lines* of two of the swiftest American steamers, I found that my professional brethren, and especially shipbuilders, were much disposed to distrust the accuracy of my statements as to the speed attained by American vessels. But my observations were correct, and the American pattern was not only very soon thereafter adopted by our shipbuilders, but was followed out with the success of which you are all aware. The American build of 1837 has been gradually adopted, and many steamers now navigate the Clyde at a speed of over 20 miles per hour, while the ocean packets

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belonging to the Cunard and Inman lines maintain a speed of 15 knots on the passage across the Atlantic.

I would refer to another instance within my own observation, where our manufacturers, finding the necessity of exertion and imitating the example of foreigners, have, within a comparatively short time, made rapid advances. I allude to the manufacture of dioptric lighthouse apparatus. About thirty years ago the manufacture of lenticular apparatus was exclusively Parisian, and the lighthouse of Inchkeith in Scotland, and the Start Point in England, were, in 1835, supplied with dioptric apparatus made in Paris under the direction of the late Mr Alan Stevenson, engineer to the Commissioners of Northern Lighthouses. During the same year, Mr Stevenson interested Messrs Cookson of Newcastle in the manufacture of lighthouse lenticular apparatus, and that firm produced in 1836, under Mr Stevenson's directions, the apparatus for the Isle of May, being the earliest first-order apparatus made in this country. It was obvious that there was a field for such manufacture, and it was thereafter taken up by Messrs Chance of Birmingham, who now are successful competitors with the French; the apparatus constructed by them is found in all quarters of the world; and the firm of which I am a member has employed them to construct from our designs apparatus for lighthouses, not only in this country, but in America, India, New Zealand, and Japan.

The two cases I have stated afford a proof of the undeniable fact that an intelligent nation, if a sufficient inducement presents itself, will profit by the example of other countries. But it does not follow that the introduction of improved steam vessels and the construction of dioptric apparatus in Britain necessarily

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imply a decline of steam navigation in America, or of lighthouse manufacture in France. I think, however, that many of the advocates of technical education in this country have been led astray by adopting some such erroneous inference. They assume that because other nations have progressed, we have declined; but all the investigations I have been able to make, while showing abundant progress made by our neighbours, do not afford any evidence of the wholesale decline of British skill which some appear to believe. The progress of other countries is, as I have attempted to show, the natural result of example, which in certain cases has been followed by our own country; and, let me add, that when in 1837 I found the steam navigation in America in so advanced a state, I found all the railways in the country laid with English-made rails and chairs, and English locomotives plying on some of their lines. But who for a moment would expect that the acute and far-seeing American people would up to the present time continue to take their rails and locomotives from England, when thirty years ago they had fairly outstripped us in their steam navigation? We have successfully followed them in that department, and the Americans, when I visited the country, were receiving their first lesson in railways; but, after receiving that lesson, they had no difficulty in assimilating their railway works to the climate of their country, the steepness of the mountains, and the circumstances of their trade, and constructing at Pittsburg and elsewhere the greater part of their own ironwork, and building all their own locomotives,—one of the results of their application of locomotives to steep gradients being the introduction of American engines into this country in 1840, for the Lickey incline of 1 in 37, on

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the Birmingham and Gloucester Railway. This spirit of imitation and competition extends even to national sports and games. Who could have expected that our famous university races should this year have presented the unlooked for variety of contesting the honours with an American competitor, Oxford beating Harvard in a race of nearly twenty-three minutes by only six seconds?

Report on Paris Exhibition by Skilled Workmen.

But let us now consider, in so far as we have elements to enable us to do it, whether I am right in assuming that the changed relations between our own and foreign countries, do not indicate that we have declined, but that our competitors have improved in manufacturing skill, and for this purpose I shall appeal to a body of testimony, the trustworthiness and value of which cannot be called in question by any one who has carefully perused it. I refer to the reports of artisans selected by the Society of Arts to visit the Paris Exhibition of 1867, and to report the information obtained.* On making known their intention to send workmen to France for this purpose, the Society was inundated with applications, and the committee to whom the duty was entrusted had difficulty in selecting the eighty skilled workmen whom the funds at disposal enabled them to send. The selection made bears ample testimony to the judgment with which the committee of the Society performed their difficult task, the result being a volume of 689 pages, containing the observations of intelligent and skilful workmen on the

* Report of Artisans selected by a Committee appointed by the Council of the Society of Arts, to visit the Paris Universal Exhibition. London, 1867.

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various branches of trade which they themselves follow. The volume published by the Society of Arts is out of print and not in general circulation, and I do not doubt that in giving the following very brief sketch of its contents, as bearing on the subject of this evening's address, I shall not be considered as unduly trespassing on your time.

The first report in the series is that of the *Cabinet-maker*, in which the following statements occur. "We "find," he says, "that the foreigners prefer Birmingham "and Sheffield steel, and we were shown tools from "London which they considered superior to their own. "As I remarked before, I consider them more proficient "in shaped work, but in preparing, fitting, and finish-"ing carcasses and inside work, drawers and dovetailing, "we are decidedly superior. In that branch of cabinet-"work to which I have been most accustomed, viz., book-"cases, wardrobes, &c., it is admitted ours is more sub-"stantial, better put together, and finished cleaner,— "our dovetailing and drawer-work is much neater as a "rule. In hanging draperies and curtains, I consider "the French throw us completely in the shade."

The *Porcelain Decorator*, a branch in which we should have been prepared to find the English inferior, reports, "that our productions at this Exhibition are "greatly in advance of all our former efforts; while in "the general commercial articles of our trade, we are "really ahead of them." Of five medals given to Minton's workmen for porcelain decoration, the jurors gave four to English, and one to a German workman; and of four medals given to Copeland's, three were given to English, and one to a German, and not one to a Frenchman at either place. "So much," adds the reporter, "for the charge of English inferiority or incapacity."

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The reporter on *Saws* and *Tools* says, that "England "is still in advance of France, Belgium, and Germany, "for the highest excellence in the perfection of model "and of a cutting edge in saws and tools;" and the *Cutler* asserts, "that in all articles which require a "keen-cutting edge, Sheffield stands at the head of all "her competitors."

The *Glass Painter* states, that "for greater variety "and graceful design in their arrangement of ornament, "I think the French are superior to us, but for richness "and a more pleasing harmony of colour, I think the "English glass painters as a body are second to none."

In *Chairmaking* and *Wood Carving* the English are reported on the whole to be deficient. A cabinet draughtsman says, "France is before us in design, but "not in workmanship;" and adds, "the palm for "workmanship must be given to Messrs Jackson and "Graham of London, whose exhibit is the finest in the "entire Exhibition."

In *Ribbons* and *Lace* the foreigners surpass us, but the English articles of hosiery were reported not to be excelled by anything in the Exhibition.

In *Pottery*, the reporter says, "after a minute examin- "ation of the various stalls, both home and foreign, I "have come to the conclusion, and the fact is forced on "my mind, that the British workman is not to be sur- "passed, if he can at all be equalled;" and the *Tile-maker* states that "in reference to the productions of "English and those of continental manufactures, after "closely examining the various collections, I have little "hesitation in stating that the continental productions "are much below the standard in comparison to English "manufactures in this branch of industry." England is reported to "stand foremost in the quality and

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" design of works in *Terra-Cotta;* and for variety and " excellence of *Earthenware, it* maintains that supe- " riority which has so long distinguished *her.*"

The *Carpenters* and *Joiners* " consider Parisian " joiner's-work to be far inferior to that done in this " country." British joinery holds its place amongst the nations of the world. Of Belgian work, " they have " little that is favourable to remark;" and America exhibits a class of work far more like the English in quality.

The *Stone Mason* claims for his own countrymen " more skill and system in executing their work, both " as regards quality and quantity;" while the *Coach-maker* reports that the foreigners do not construct their work with such effectiveness and durability, and " sees " nothing yet to tarnish the reputation of English " coachbuilders."

An interesting report follows on *Shipbuilding,* in which the author says, " I was very much surprised by " the scarcity of work connected with that class, with " the exception of that sent by England, which was " very good and plentiful."

In *Silver-work* it is stated, " we see at once that " France and England occupy the first rank as pro- " ducers of high-class art work in the precious metals, " and of the two the superiority must be acknow- " ledged to be on the side of France."

In *Hammered Iron* also, the only competitors of consequence are said to be French and English. The former excel in taste and effect, but they are not more skilful as smiths; the reporter adds, " in fact, I think " the English excel" in that department. Another reporter on *Ornamental Iron* thinks " the English are far " behind the French," but that these two countries are

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the only competitors. Three reports are given on *Watchmaking*. In one it is stated that England "still "maintains her superiority in substantiality of work-"manship and system for accurate time keeping;" in another, the English watch and chronometer maker is said "still to stand at the head of his profession;" while the third, on clockmaking, states, that in this branch "the French surpass in every point."

In *Tailoring*, it is the reporter's conviction "that "the west-end tailor of London is by far the best, and "greatly the quickest workman."

The reporter on *Bookbinding* says, "the works "exhibited by England, form as fine a collection as the "nineteenth century has produced, and it is therefore "no matter of surprise that the majority of medals for "binding were awarded to the English." The worker in *Leather* says, "nothing which I could take as a "sample of national skill would, in my opinion, equal "the production of the English manufacturers."

In *Worsted Yarns* and *Mixed Textile Fabrics*, the French are reported by two different reporters to be superior, and of the machinery for manufacturing such fabrics, it is stated, "it is impossible to find any "within the precincts of the Exhibition, or elsewhere, "to compare with the English." This same reporter further states, that every exertion is being made by foreigners to supersede us in these departments of trade.

Next come important reports from *Mechanical Engineers*, from which I quote the following extracts:— "For finish and sound workmanship, I saw nothing to "surpass the British display. Amongst all the other "nations, including the French, the machinery was of "a heavy build, with much waste of metal, and evi-"dence of want of skill in design. Before visiting

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" Paris, I had heard much of French and Belgian " locomotives, and their cheapness and superiority over " ours, but I have not the slightest hesitation, after " having carefully looked at all the specimens of this " class of work which I could find in the French, " Prussian, and Belgian courts of the Exhibition, in " saying that the best foreign locomotives were but " bad copies of English originals."

Twenty-five artisans were nominated by the Birmingham Chamber of Commerce to report on twenty-two distinct branches of local industry, such as *gas-fittings, church bells, saddlery, jewellery, toys, buttons, steel pens,* and other wares of Birmingham manufacture. To these reports I cannot now refer in detail, but I have carefully perused them, and the conclusions arrived at by these reporters are very similar to those already quoted, Mr Aitken, the writer of the introductory report of the series, coming to the conclusion " that there are no evidences of any decadence what- " ever in the manufactures of England as shown in the " French International Exhibition just closed."

Their Opinion as to Sunday Work.

But, before leaving the very interesting and instructive volume of reports, to which I have at such length referred, it would be unpardonable did I not advert to what forms a most prominent, and, I may be allowed to add, to my mind a most pleasing feature of these valuable documents, confirming, as it does, my own views, after thirty years' experience in the conduct of public works and the habits of workmen. I mean the unanimity of all who report on the social question on two most important subjects—the virtues of the English home system and the pernicious effects of Sunday labour.

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After fully describing the foreign workman's life and habits, one of the reporters goes on to say—"All is "not gold that glitters, for, among all the enjoyments "of a Parisian workman, there is nothing to compare "with the substantial comfort of an English workman's "home, or the quiet repose and respite from labour which "the Sabbath brings him." This is but an echo of the views expressed by these British workmen. All of the reporters, without exception, who allude to Sunday work condemn it; and, so far as I could see, there was only one reporter who, to improve the taste of art-work in England, suggests the opening of our museums for Sunday study. But even he, while disapproving himself of Sunday work, appears to forget that the course he suggests would only add another day to the workman's task, substituting for the toil of the factory the more trying mental study of the fine arts. For, as is most justly said by another of the reporters, "we "rest on the seventh day, and are therefore more "workable on the other six. As for the rest which "is obtained by exploring museums and studying "pictures, I am quite certain that an employer would "get more work on Monday out of a man who had "passed the day before in the factory than from the "one who had been all the Sunday improving him-"self by instructing his mind."

The Author's own Observations on the French Exhibition.

Allow me very shortly to add to the testimony of the artisans whose words I have so fully quoted, the result of my own observation on the French Exhibition of 1867, which I visited at the request of the Commis-

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sioners of Northern Lighthouses, to report on the department of lighthouse engineering. I found that in variety of design the dioptric apparatus exhibited by the Commissioners of the Northern Lighthouses had a decided advantage. The French glass of the lenticular portions of the apparatus was purer than the British, who, on the other hand, excelled in the fineness of finish, in the machinery, and, on the whole, I reported to the Board that "I did not find any novelty in design "or construction worthy of special remark."

Now, it is well to recall attention, in passing, to the fact, as already noticed, that the construction of dioptric apparatus was, I may say, until late years wholly French, and that nation may truly affirm that in this most important manufacture they have been, if not excelled, at least equalled by Britain in the course of the last thirty years.

Though present at the Exhibition professionally, to report on a particular branch of engineering, I, in so far as time admitted, examined the mechanical engineering department, and I certainly came to the conclusion, that to a visitor, judging from what can be seen on an outward inspection, the locomotives and other engines from British exhibitors, as respects finish, held a very favourable place as compared with those of the other nations exhibiting. It is true that in large marine engines, and in large iron forgings, we were quite surpassed; and if *size* is to be taken as a criterion of perfection, we should certainly have nothing to say on behalf of our acquirements; but the country in which the Exhibition is held has enormous advantages, particularly in the production of large machinery. At what sacrifice to the exhibitor could large marine engines and forgings, such as those exhibited by our

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foreign neighbours, have been transferred by us for exhibition in the Champs de Mars!

After observation on the spot, then, and careful study of all the evidence I could procure, I have no difficulty in concluding, *First*, That any alteration on British manufacturing pre-eminence and monopoly since 1851 is due not to decline of British workmanship, but to increased excellence of the work of foreign nations. *Secondly*, That in most departments of trade Britain still maintains pre-eminence in skill; and *Thirdly*, That the departments where the foreigners excel in skill are those chiefly of art workmanship.

Improved Education Necessary.

But now the question may fairly be asked, Is then the present system of education in this country, both in its character and extent, sufficient, and do we require to make no effort to maintain, if not to improve, our manufactures? Have we, in short, attained perfection? And to this question we have no hesitation in giving a negative reply. Improved education and increased exertion are every year more loudly called for. No one will venture to dispute, as indeed is fully borne out by the Artisans' Reports, that in all departments of art workmanship the foreigners—in the fine examples constantly presented to the workman's view, and in the thorough training afforded by their schools of design—show us an example worthy of our careful imitation. But while this may be fairly admitted, we cannot join in the sweeping cry that has been raised, that our workmen in all departments are losing their cunning, and that all this is due to the want of technical education.

Mr Russell says, "The English are not an educated "people. They are, at least, an ill-educated people.

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"They educate themselves as best they may; the blind "lead the blind. They have fallen behind their rival "nations. They have been abandoned to their fate, "and they suffer." I can hardly conceive a more satisfactory refutation of this general condemnation than the highly creditable volume of artisans' reports, to which I have referred. A selection, I will venture to say, of more ably written documents, replete with more valuable information, could not be produced by the workmen of any nation in the world.

Some views as to Education of Workmen not sound.

If, indeed, I held the views expressed by some writers as to the extent and kind of education necessary to prepare the workman for his duty, I should, perhaps, be driven to adopt those terms of wholesale complaint. For it has been asked, "Why should not the miner "find compensatory pleasure for the darkness of the "mine in a knowledge of the gases by which he is "surrounded, and of the minerals he is extracting?" "The intelligent ditcher," it has been said, "should so "arrange his work before he puts a spade in the soil that "every bit of earth is moved out of its old place into its "new the shortest way over the least distance, with the "least force." Now, I cannot help thinking that such views are, if not purely fanciful, at least very impracticable. All education which can tend to make a workman excel in his style of workmanship cannot be too highly commended, but it is obvious that *all* education does not tend to this. To take an example: it is clear that to the stone-mason, as such, it can be of no value that he should be able to tell whether the stone he is working be from the Coal-measures or the Old Red Sandstone, whether it be a granite or a syenite. But if he

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be employed in the finer or ornamental departments of masonry, it is equally obvious that a knowledge of drawing and design may greatly tend to improve his style of workmanship, and facilitate its execution. And hence we may safely conclude that it cannot profit the mason's manipulation to study geology, whereas he may attain much benefit from attending a school of design.

What constitutes a First-class Workman.

It seems to me that in the desire to impart to the working-classes a *general* course of study, much harm may be done; for it must be kept in view that the possession of ten fingers, coupled with a large store, it may be, of head knowledge, does not necessarily give the power to any lad to become an accomplished workman. To excel in handicraft is a gift possessed in different degrees by different persons, just like excellence in classical or scientific accomplishments; and it is only, at best, by an early apprenticeship to the work, and a patient practice of it, that most persons, even though having what is called a *mechanical turn*, are enabled to acquire perfection; and it would be exceedingly undesirable to employ either the heads or the time of apprentices in studies which have not the direct effect of improving their manipulation and management of the materials with which they have to deal. The recent advocates of improved technical education, in their zeal for head knowledge, have given to perfect manipulation greatly too subordinate a place; and in the educational arrangements they propose, they do not consider and provide for the time and difficulty of acquiring those high manipulative attainments which every skilled workman should aim to possess. Because,

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after all, let me ask, what is it but manipulative superiority that gives success to any branch of manufacture, and what but laborious practice, coupled with some amount of natural aptitude, will ever make a first-class workman?

What ought to be a Workman's Study.

What, then, ought to be the education of such a man? Clearly every branch that can help him to perfection in work, but as clearly nothing that will simply occupy his time without furthering the all important acquisition of manipulative skill.

Education may be too general.

And here let me say a word as to the acquisition of general knowledge, because we shall err greatly if it is made *so general* as to fail in producing substantial practical results. The advocates of this general, I may almost say indiscriminate, education would propose, for example, that agriculturists should know some fifteen different branches of study, among which, according to Mr Russell, are the nature of soils—the structure of plants—the food of plants—manures—the diseases of animals—the laying out of farms—the construction of farm buildings—and other similar branches of study, all of which are to be learned at technical schools or universities. Our objection to all this is that no man can acquire and practically apply with success all these branches, and, without presuming to define what agricultural education should and what it should *not* embrace, we should infinitely rather see the agriculturist apply his mind to the difficult task of successfully working his farm, and, when occasion requires, getting the assistance of the accurate and experienced land-

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surveyor for his measurements, the architect for his farm buildings, and the veterinary surgeon for the diseases of his horses and cattle. Why, in the profession to which I belong there is a wholesome and advantageous separation of its wide-spread subjects, and a corresponding division of work among its members. We have harbour and river engineers, railway engineers, lighthouse engineers, water-works engineers, electric engineers, gas engineers, mechanical engineers. No one mind can grasp the theoretical knowledge, and no one life can compass the practical experience to enable men to attain eminence in all these departments of engineering, and how is it to be expected that the agriculturist is to master the varied subjects proposed for his study with such intelligence and success as to warrant his practising as a surveyor or an architect without the chance of being led into grave error? The same subdivision, indeed, holds in labour; even the simplest operations of manufacture are, as is well known, in order to attain cheapness and perfection of workmanship, entrusted to different classes of workmen who are each exclusively employed in that department in which they chiefly excel; all this pointing to the important conclusion, that to attain perfection you must have recourse to subdivision of labour, and this again leading inevitably to the inference, that there are limits beyond which education cannot be usefully or beneficially pushed.

General Propositions for regulating National Education.

Now, in attempting to define these limits, I think we may be assisted by keeping in view the following general propositions:—

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First, That the *elementary* or *primary* education of the schoolboy cannot be too perfect consistent with the boy's capacity, and the time that can warrantably be allowed to it; and this remark is of *universal* application, and ought to embrace *all British subjects.* Whether the *primary* education should be voluntary or compulsory, denominational or national, is not our object at present to inquire, and the ensuing session of Parliament is likely to decide.

Second, That a certain amount and kind of *technical* education would be invaluable for certain classes of workmen, especially those in the department of art work, but this teaching, too, must not unwarrantably interfere with the time and practice requisite to enable the lad to acquire the manipulative part of his business, which is what makes the skilled workman; and therefore technical differs from primary education, inasmuch as it is not only *not* applicable to *all*, but, to be successfully carried out, much discrimination must be used in determining for what branches and to what extent it may be beneficially employed; and,

Third, That the acquisition of *general* knowledge, such as may be got by attending lectures, schools of arts, and otherwise, may safely be left to the taste and discretion of the workman, and must depend chiefly on the position to which he aspires; but as *all* cannot be foremen or managers, it is obvious that technical and general education, as I have defined them, cannot be regarded as of essential importance to the great bulk of the working-classes.

I think these propositions, or something like them, should form the groundwork of any legislation in this important matter, and with the extension, and perhaps improvement, of existing educational institutions, and

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the full development of the advantages already afforded by our Government department of Science and Art, as detailed in the Directory published with their sanction, together with the countenance and co-operation of the more intelligent and advanced of the working classes of the country, I fail to discover the necessity for such gigantic and expensive educational projects as those to which I adverted in the opening part of this address.*

Effects of High Wages and Restricted Foreign Trade.

But it still remains for me to direct your attention to what has all along appeared to me as by far the most serious aspect of this important national question. Had the difficulty in dealing with the improvement and maintenance of our manufactures been only *educational*, it might have been effectually and satisfactorily overcome, even had our national deficiencies in this respect been so great, and additional schools and colleges so urgently required, as the most strenuous supporters of the educational movement represent. The country, I am sure, would not grudge any cost required to attain so desirable an object. But it seems to me that we have to deal with difficulties which mere money cannot overcome, and Government interference cannot wholly reach—difficulties the mastery of which will, I venture to predict, ere long tax to the utmost the energy and the self-denial of the British nation. But what are these difficulties? Foreign countries have now, as we have seen, given their attention to manufactures; they have undeniably in their own people the minds and the hands to do the work. Britain is freely thrown

* "Directory, with Regulations for Establishing and Conducting Science Schools and Classes." London, 1869.

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open to receive the products of their labour, and the simple question now is, Who can produce good work at the cheapest cost? This is a view of the matter in which our foreign friends have great advantages, and to this, I believe, coupled with foreign restrictions on the introduction of our manufactures, we may chiefly trace the altered position which industrial Britain occupies among the nations of the world. The habits and dress of foreign workmen are in every way more simple than ours; their rate of pay is greatly lower, and they can turn out their work at a price with which the high wages of this country render it impossible for us to compete; and with us wages are still increasing. In my own experience, indeed, I am enabled to state that the wages now paid at Dhu Heartach Lighthouse Works exceed by upwards of 30 per cent. those paid at the works of Skerryvore Lighthouse, which was executed thirty years ago in the same part of the country, and under precisely similar circumstances; and since then, it is proper to remark, the price of ordinary provisions has risen in nearly the same proportion. Mr Thornton, in his interesting book on Labour, says, "In no other "old country, either in ancient or modern times, has "the average rate of wages been nearly so high as it "now is in England."*

Let me give an illustration out of many that may be cited of the practical working of this state of matters. An extensive shipbuilder in this country lately gave an offer for a contract, as he thought, at an almost unremuneratively low rate. The work was let to a foreign firm, and on visiting the country shortly afterwards he saw, on the stocks, the vessel for which he had offered,

* "On Labour, its Wrongful Claims and Rightful Dues, its Actual Present and Possible Future."—*William Thomas Thornton.* London, 1869.

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and he told me that, on inquiry, his loss of the contract was quickly solved, as he found that the wages paid to some of the skilled workmen in that foreign shipbuilding yard were less than one-half of what he was paying at home! The Trinity House of London requiring dressed granite blocks for the Longships Lighthouse, accepted the lowest offer, being that of a firm in Dinan in Brittany; so that even in the very heart of our granite district of Cornwall the English workman is undersold in producing stones to build a lighthouse on the shores of his own country. There cannot be a doubt that foreigners can now produce work in all departments, so excellent, that any deficiency in *finish*, as compared with our own, is more than compensated by the lowness of its price; and in those few departments where they excel us in high workmanship, its lower cost gives them of course a still greater advantage in competing in *our* markets, while, by imposing even a trifling duty on our manufactures, they have it in their power to shut us out entirely from *their own*.

Now, these very grave considerations have led me to direct your attention this evening to our national manufactures; and in order to bring that subject before you in all its aspects and in all its importance, it was necessary that I should take exception to the opinion so widely expressed, that the skill of our workmen has declined; and on this point I trust you are satisfied from the evidence I have been able to lay before you; and it was further necessary that I should combat the idea that improved technical education would remove the whole of the difficulties under which our manufactures are on all hands admitted to be suffering. I have, in short, endeavoured to show what I believe to be the case, that it is neither decline in skill nor want of

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education that is really depressing the trade of this country at the present time, but that the chief cause of our difficulties is the lower cost at which the industries of foreign countries can be produced, and the more favourable circumstances under which they can be sold; so that *if this be true*, it follows as a consequence, that so long as foreigners can exist on lower wages than British subjects, and British manufactures are subjected to foreign duties, and British skill is hampered by restrictive trade regulations, so long shall we have to listen to the same cry of foreign pre-eminence. Mere education, assuredly, will not grapple with and overcome the difficulty. Neither would our immediate return, as a nation, to the *general* imposition of duties on foreign articles help us. The effect of that would be to raise the prices of provisions, already admittedly high. Reciprocity in free trade, if attainable, would, indeed, not only seem reasonable and just, but would have, unquestionably, some effect in improving our commercial relations, though neither would that *alone* entirely remedy the evils from which our commerce suffers.

Desirableness of Friendly Relations between Employers and Employed.

The cure, it seems to me, must rest *chiefly* and *primarily* with the working men themselves and their employers; and if between them they cannot devise some means whereby British work can be manufactured and sold at something like foreign prices, we must be content, I fear, to resign our national manufacturing pre-eminence, and meekly to succumb to the advantageous position of our foreign competitors,—unless, indeed, foreign habits should alter, and foreign wages should increase in some such ratio as our own; but it would

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be neither wise nor politic to rest satisfied with an expectation, the realisation of which is at the best uncertain, and certainly very distant. But is there not still hope for us? Is it not the case that as yet there has been too little deliberative and friendly communication between the employers and the employed on this most urgent and important subject? Instead, for example, of the Trades Union Congress at Birmingham this season unanimously adopting a resolution, declaring that "while strikes and lock-outs had extended poverty to workmen and frequent bankruptcy to employers, they had in many instances advanced the interests of the working classes by raising their wages and shortening their hours of work," would it not be wiser, at the next annual meeting of the Union to be held at London, to discuss the expediency of holding a *general national* conference of delegates, representing the employers and employed in all departments of trade, to consider the subjects of the profits and wages of our own and of foreign countries—the effects of Unions—and the laws which regulate the interchange of British and foreign manufactures?

Instead of *antagonism* between employer and employed, let us rather see intelligent and thoughtful co-operation, if we desire that Britain should cope with its formidable rivals. The interests involved are momentous, and the combatants numerous and influential, represented on the one hand by the manufacturers and their capital, and on the other by the workmen and their Trades Unions. Both might be cordially united in one common effort to save our country's manufactures and promote their common good. We do not blame either party for protecting their rights by all lawful means, but so long as their exertions are an-

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tagonistic and hostile, commercial depression must continue; and the manufacturers will ultimately find, perhaps when it is too late, that their capital will be unremunerative, and the workmen that high wages and short hours will not restore diverted or declining trade.

Trades Unions.

It is no part of this address to discuss the subject of Trades Unions, but I cannot well avoid noticing their important bearing on the price of labour—one of the topics which we have been discussing. These powerful associations number, it is believed, about 2000. Mr Thornton, himself an advocate for Unionism in a restricted form, says, "Regarded financially, some of the "associations will be found to have resources sufficient, "on occasions of great emergency, to admit of a single "union devoting L.50,000 or L.60,000 to the require- "ments of a single season. The Amalgamated En- "gineers, indeed, do nearly as much as this habitually. "In 1865—a normal year—their income was L.86,885, "and their expenditure L.49,000. They have at pre- "sent an accumulated fund of about L.140,000." That the affairs of these large associations cannot be conducted at small cost, must be apparent, and Mr Thornton, as an example of this, states that "the Sheffield "Operative Bricklayers held a meeting of delegates to "revise its laws; it sat for a fortnight, and cost the "society L.1088."

I quote these financial statements of Mr Thornton, as their effect in connection with the rate of wages is very important, and deserves most serious consideration; and in conclusion, I would only repeat that the whole subject is *eminently* one for the friendly and dispassionate attention of manufacturers and workmen.

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Certain it is thatour manufacturers and workmen cannot be charged with want of enterprise and skill, but it is no less true that without some change in wages—in manufacturers' profits—in prices of provisions—in reciprocity of free trade,—or perhaps, more properly speaking, to some extent in all of these conditions—no educational movement, however complete its system or extended its sphere, can serve to maintain British manufacturing pre-eminence, for foreign nations will, so long as they can maintain low wages, continue to undersell us.

The great length to which these remarks have extended forbids me to trespass farther on your patience this evening. I should have wished to have been able to offer a few biographical notes as to some of our Members whom we have lost by death during the past session, particularly, as among the number is the name of James David Forbes, a former President of this Society, the Principal of the United College of St Andrews, and for twenty-seven years the distinguished Professor of Natural Philosophy in our University; but time will not permit me to do more than to read the names of our deceased Members in alphabetical order, as furnished to me by the Secretary. They are—Robert Bird, gas manager; Robert Burn, engineer; James D. Forbes, Principal of United College, St Andrews; Humphrey Graham, writer to the Signet; John Greig, of Eccles, writer to the Signet; Robert Kemp, plumber; Thomas Leburn, solicitor; Colonel Alaric Robertson; Neil Robson, civil engineer; and Dr William Sellar;—in all, ten in number. There have also been a few resignations. Eighteen new Members have joined the Society, resulting in a gain of one Member, the total number of Fellows now being 434.

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On the Economic Distillation of Gas from Cannel Coals. By Dr Stevenson Macadam, F.R.S.E., F.C.S., Lecturer on Chemistry and Analytical Chemist, Edinburgh.*

The experimental observations which form the basis of the present communication were undertaken for the purpose of determining the quantity and quality of gas obtained from certain mixtures of cannel coals distilled together as compared with the gas yielded by the same coals taken separately. The coals selected for examination by destructive distillation were sixteen in number, and they comprehended examples of some of the larger coal-fields in Scotland. The experiments were conducted in a small gas work constructed and fitted up by Messrs Milne & Son, gas engineers, and attached to the laboratory of the author. The gas work was connected with fully equipped photometric apparatus. The quantity of coal experimented upon at a time was six pounds, and the volume of gas yielded therefrom amounted to about 30 cubic feet. Every possible care was taken to keep the retort at a uniform temperature during the course of the trials, and the testing of the same coal on several occasions showed that such was practically done.

The coals employed in the experiments, and the quantity and quality of gas obtained therefrom, may be observed from the following table (Table I.)

Considering the original cost of the coals, the eight samples marked with an asterisk were selected as most economical, and the basis was laid down that one ton of the coals or mixtures of coals should yield 10,500 cubic feet of gas of thirty candle power. Calculations were made so as to observe what coals or mixtures of such ought to yield the requisite quantity and quality of gas, and the coals were used in the definite proportions calculated to yield the best results. The second series of trials proved that the illuminating power of the gas obtained from the mixtures of coals, as determined by experiments, was always in excess of that arrived at by calculation from the quality of the gas given

* Read before the Society 22d November 1869, and awarded the Society's Silver Medal and Plate, value Five Sovereigns.

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TABLE I.—*Yield and Quality of Gas from Cannel Coals taken Separately.*

Name of Coal.	Gas per ton of Coal in cubic feet.	Illuminating power of the Gas (five cubic feet per hour) in Candles.	Cost of 10,500 cubic feet of Gas of 30 Candle power.	
			s.	*d.*
*1. Bredisholm or Provanhall, . .	9,434	26·81	12	5½
2. Shields, . .	10,703	21·22	13	10½
3. Bank, main seam, ...	11,524	19·82	18	7½
*4. Cleugh, . .	11,452	29·39	14	11¾
5. Wilsontown, .	10,666	25·31	18	11½
*6. Muirkirk, . .	10,552	37·16	16	10½
7. Rigside, . .	11,490	32·31	20	4½
*8. Climpy, . .	10,928	38·68	18	7½
*9. Bank, 5 ft. seam,	9,768	27·07	16	1
*10. Pollock, . .	11,525	30·26	14	0
11. Huntershill, .	10,030	22·66	12	5¾
12. S. Boig or Lower Lanemark, .	9,881	24·39	17	7¾
13. Upper Lanemark, ...	10,479	24·56	16	6¼
14. Raploch, . .	10,966	17·05	16	10
*15. Haywood, . .	11,153	30·97	15	6
*16. Kinneil, . .	11,789	30·60	17	0¼

by the individual coals taken separately, as may be observed from the following table (Table II.)

These results will probably be best contrasted by throwing the quantity and quality of the gas into pounds of sperm, and the following table gives the results of the illuminating power of the coals and mixtures of coals, as determined by calculation from the yield of the individual coals taken separately and the respective proportions obtained by the distillation of the coals previously mixed.—The value in each case being given in pounds of sperm:—(Table III.)

The increase in illuminating power is undoubtedly due to the presence of a larger proportion of the heavy hydrocarbons, as the condensation of bromine rose in each trial on an average of one per cent. of increase. The larger proportion of the heavy hydrocarbons may probably arise from several causes.

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TABLE II.—*Gas from Cannel Coals taken Separately and Mixed.*

	Quantity and Quality of Gas from One Ton of Coals taken Separately.	Quantity and Quality of Gas from One Ton of Mixed Coals—Calculated.	Quantity and Quality of Gas from One Ton of Mixed Coals—Experiment.
No. 1. Pollock, . . .	11,525 C. F. at 30·26 Candles		
No. 1. Pollock, 2d trial,	11,013 „ 31·52 „		
No. 2. { 1 Bank, 5 ft. seam,	9,768 „ 27·07 „	10,806 C. F. at 30·09 Candles.	10,714 C. F. at 32·27 Candles.
3 Haywood, . .	11,153 „ 30·97 „		
No. 3. { 1 Provanhall, . .	9,434 „ 26·81 „	10,479 „ 31·22 „	10,677 „ 32·96 „
1 Cleugh, . . .	11,452 „ 29·39 „		
1 Muirkirk, . .	10,552 „ 37·16 „		
No. 4. { 1 Provanhall, . .	9,434 „ 26·81 „	10,722 „ 30·73 „	10,938 „ 32·86 „
2 Cleugh, . . .	11,452 „ 29·39 „		
1 Muirkirk, . .	10,552 „ 37·16 „		
No. 5. { 2 Provanhall, . .	9,434 „ 26·81 „	10,618 „ 30·94 „	10,603 „ 33·32 „
3 Cleugh, . . .	11,452 „ 29·39 „		
2 Muirkirk, . .	10,552 „ 37·16 „		
No. 6. { 1 Climpy, . . .	10,928 „ 38·68 „	10,540 „ 30·30 „	10,565 „ 32·91 „
2 Provanhall, . .	9,434 „ 26·81 „		
2 Cleugh, . . .	11,452 „ 29·39 „		
No. 7. { 4 Haywood, . .	11,153 „ 30·97 „	10,809 „ 30·24 „	10,640 „ 32·19 „
1 Provanhall, . .	9,434 „ 26·81 „		
No. 8. { 1 Kinneil, . . .	11,789 „ 30·60 „	10,882 „ 29,97 „	11,125 „ 31·38 „
2 Haywood, . .	11,153 „ 30·97 „		
1 Provanhall, . .	9,434 „ 26·81 „		
No. 9. { 1 Kinneil, . . .	11,789 „ 30·60 „	11,011 „ 30·03 „	10,752 „ 32·48 „
2 Haywood, . .	11,153 „ 30·97 „		
1 Provanhall, . .	9,434 „ 26·81 „		
1 Pollock, . . .	11,525 „ 30·26 „		
No. 10. { 2 Provanhall, . .	9,434 „ 26·81 „	10,553 „ 31·43 „	10,864 „ 33·96 „
2 Haywood, . .	11,153 „ 30·97 „		
1 Cleugh, . . .	11,452 „ 29·39 „		
2 Muirkirk, . .	10,552 „ 37·16 „		

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TABLE III.—*Gas from Cannel Coals taken Separately and Mixed.*

Names of Coals.	A Illuminating power of the Gas from one ton of Coals in lbs. of Sperm, calculated from separate results.	B Illuminating power of the Gas from one ton of the Coals, in lbs. of Sperm, calculated from mixed results.	Difference in favour of results from the Mixed Coals.	Percentage of Increase in Illuminating Power, A and B.
No. 1. Pollock, . . .	1195·70	1190·16	Only one Coal in this trial.	
No. 2. 1 Bank, 5 feet seam, 3 Haywood, . .	1114·81	1185·39	70·58	6·33
No. 3. 1 Provanhall, . . 1 Cleugh, . . . 1 Muirkirk, . .	1121·67	1206·56	84·89	7·57
No. 4. 1 Provanhall, . . 2 Cleugh, . . . 1 Muirkirk, . .	1129·67	1232·45	102·78	9·09
No. 5. 2 Provanhall, . . 3 Cleugh, . . . 2 Muirkirk, . .	1126·36	1211·29	84·93	7·54
No. 6. 1 Climpy, . . . 2 Provanhall, . . 2 Cleugh, . . .	1094·95	1192·09	97·14	8·87
No. 7. 4 Haywood, . . 1 Provanhall, . .	1120·68	1174·29	53·61	4·78
No. 8. 1 Kinneil, . . . 2 Haywood, . . 1 Provanhall, . .	1118·17	1196·92	78·75	7·04
No. 9. 1 Kinneil, . . . 2 Haywood, . . 1 Provanhall, . . 1 Pollock, . . .	1133·76	1197·34	63·58	5·68
No. 10. 2 Provanhall, . . 2 Haywood, . . 1 Cleugh, . . . 2 Muirkirk, . .	1137·03	1264·94	127·91	11.25
Average percentage of Increase in Illuminating Power 7·57 or 1-13th of the whole light obtained as gas from one ton of the coals.				

(1.) The intermixture of the lighter gases of the inferior coals with the heavier gases of the better coals, thus tending to save the heavy hydrocarbons from being decarbonised or reduced by the heat of the retort.

(2.) The mixture of the lighter gases with the heavier gases and vapours tending to keep the latter from separating in the condensers, purifiers, and gasholder, and ;

(3.) Probably also, the reaction of the gaseous bodies upon

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each other during the moment of their liberation from the coal by destructive distillation, and when the gases are in the condition recognised as that of the nascent state, and when, as is well known, chemical reaction is most energetic.

In England so much attention is paid to coke, that necessarily the quality of the resultant fuel obtained from mixtures of coals must be considered. In all the experimental trials referred to in this paper, the mixed coke was at least of fair quality, and could be used with advantage in the furnaces. The general result of the inquiry therefore is, that given a certain quantity of coals of different gas-producing powers, it is more economical to mix these coals, and heat the mixture in the same retorts at the same time, than to distil each coal separately in different retorts and thereafter mingle the gases in the ordinary way.

On Braced Arches and Suspension Bridges. By Professor Fleeming Jenkin, M.I.C.E., F.R.SS. L. & E.* (Plates I., II.)

The experiments made in connection with the Britannia Bridge established the theory of metal girders on a sure practical basis, and with the inquiry of a Royal Commission into the application of iron to railway structures, have led not only to the general adoption of the iron girder as a convenient type of bridge, but also to a widespread belief that essentially the girder is a cheaper and lighter form of support than the metal arch. The suspension bridge indeed, the theory of which is identical with that of the arch, is known to be a lighter form of support than the girder; but an impression prevails that the flexibility of the form cannot be really overcome without sacrificing the lightness, and although this prejudice has been gradually yielding, the assertion that a stiff suspension bridge may be advantageously used for moderate spans will be received with doubt; while a statement that a cast iron arch might not only be safely used for spans of 700 or 800 feet, but would be lighter than a girder for ordinary spans, will excite simple incredulity among practical men.

* Read before the Society 13th December 1869, and awarded the Hepburn Prize, value Seven Sovereigns.

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A little consideration, however, shows that there can be no essential superiority in the girder over the two other forms. Taking the depth of the girder, the depth of the suspended chain, and the rise of the arch as analogous dimensions, the strains at the centre of each, with similar uniform loads, are identical. These strains are nearly constant throughout the single member in the arch and chain. On the top and bottom members of a girder the strains diminish towards the supports, but the addition of the diagonals or centre web renders the girder essentially far heavier than the arch or chain for this particular load. Next comes the question of varying or passing loads, and here we reach the secret of the universal prevalence of the girder. The passing load on a girder requires no modification in the top and bottom booms, and the modifications required in the centre web or diagonals are calculated with ease and certainty; whereas the corresponding calculations in the case of the arch or suspension bridge have either been impossible or exceedingly difficult.

The mode adopted of calculating the strains in a metal arch has until the last few years been simply barbarous, and the distribution of the metal in those arches the worst possible. Mathematicians found the task of calculating the strains on a metal rib so complex that they abandoned the task, and engineers made a rough guess at the strains which simply enabled them to build bridges, in which, by a lavish expenditure of metal, they were at least sure that the bridge would not fall. Lately the idea that a suspension bridge might be stiffened so as to be practically useful has gained ground, and Professor Rankine by theory, and Mr Barlow by experiment, demonstrated that a comparatively light stiffening girder added to the flexible chain was sufficient. The same idea was obviously applicable to the arch, and thus, in Professor Rankine's "Applied Mechanics," we find this idea suggested, and in the Civil Engineering examples are given of efforts in the direction of braced arches.

The main problem has, however, been left unsolved. Men have first of all assumed that there was to be a chain or main arch, taking the main strains, and have then in-

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quired how this chain or arch was to be stiffened to meet special loads, whereas the problem really before us might be stated as follows:—How shall we distribute the metal in a compressed arch or extended chain so as to obtain a maximum of strength with a minimum of material? This is the problem which has been solved for girders, and has led to their universal adoption; it is the problem which has remained unsolved for chains and arches.

The reason for this may be found in the words of Professor Rankine, where, speaking of a braced rib continuous at the crown as distinct from a mere pair of strutts shaped to look like an arch, he says,—"The exact determination of the state of stress at different points becomes a problem of almost impracticable complexity." He then proceeds to give an approximate method, founded upon a complete investigation of the arched rib of known section, given, I believe, for the first time by him in the same work. The present paper is intended to give a true and not over complex solution of the general problem, which, being solved, will show the extraordinary advantage to be gained by designing arches and suspension bridges upon sound principles.

Few engineers are aware of the difficulty of calculating the strains on a stiff arched rib held between abutments. In truth, unless the yielding of every part of the structure, including the abutments, be taken into account, the strains are indeterminate.

When a girder rests on two supports we have no difficulty in finding the reaction or thrust due to each pier, because the direction must necessarily be vertical, and the total load carried by each pier being known, we can start from this single resultant at each end and calculate every other stress, on framework, for instance, by the simple resolution of forces.

But suppose, instead of resting on horizontal planes, leaving them free to move endways, the ends of the girder were rigidly held as if jammed, for instance, between two inclined surfaces. Then the strains, on all ordinary theories, become indeterminate. We do not know the direction of the resultant at the piers, and there are an indefinite number of sys-

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tems of stresses under which the frame would be equally in equilibrium. We do not know what the amount of the horizontal force is which we have introduced or may introduce by fixing the ends rigidly.

Now, this is precisely what occurs with every stiff rib or stiffened chain. The direction of the thrust at the abutments is indeterminate until we have taken into account the stiffness of the rib and yield of the abutments. It has been common to assume that, with a uniform load, the direction of the thrust would be tangent to the curve of the rib; but this has been mere assumption, and when the load has been unsymmetrically distributed, this assumption being obviously untenable, engineers have been puzzled what other assumption to make, and have proceeded by sheer guess work. No stress in nature is, however, really indeterminate, and a method of calculation introduced by Professor Clerk Maxwell enables us to solve this problem, and the solution has led to remarkable conclusions.

The author in 1861 perceived that the true form of a stiff rib or chain would be that in which two members should be braced together as in the girder; but whereas in the girder one member was in compression, and the other in tension, in the braced arch both members might be compressed, and in the suspension bridge both extended. The only effect of varying the distribution of load on such structures would be, that the thrust would at one time be such as to throw the chief strain on the upper, and at another time on the lower member. In this way a stiff frame could be produced which was essentially an arch or a suspension bridge, differing from the girder, which essentially contains one member which shall be extended, and one which shall be compressed.

He found, however, that he was unable to calculate, except on unproved assumptions, the true distribution of strains on the framework, being unable to determine the resultant thrust; but having drawn Professor Maxwell's attention to the problem, he discovered and published, in the "Phil. Mag.," May 1864, a method by which the resultant and all stresses in framed structures could be positively determined.

The following is an abstract of the method and of the

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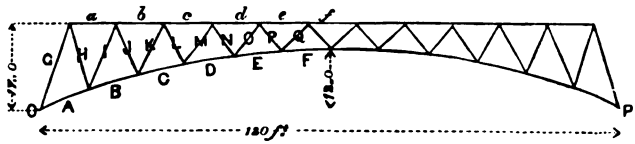
reasoning by which it is established, put into a form in which it will be more readily understood and applied by practical men. Let us assume a single load to be applied at any one of the top joints of the frame fig. 1. This load will produce an inclined stress at each abutment; let us call the vertical and horizontal components of this stress at the abutment O, V and H respectively.

Now, consider the relation between the extension or compression of the line OP and the extension or compression of any member of the frame a, situated between abutment O and the point of application of the load, these changes in length being supposed due to the action of the single load.

FIG. 1.



Supposing all the members to be rigid except a and the line OP, the simultaneous changes in the lengths of these two lines will bear a fixed ratio to one another. Let the change in the length of the line OP be called y, and the simultaneous change in the length of the line a be called x; these changes being due to the action of V, H, and the load; x will be positive if the member is compressed, and negative if it is extended. y in the particular frame will be negative, corresponding to the extension produced by the load in the line OP.

Let q be the stress which the unit force (one ton), acting along the line OP, would produce on the member a; q may be positive or negative. Then, by the principle of virtual velocities—

$$x : y = 1 : q,$$

the spaces x and y being inversely proportional to the stresses q and 1. Thus, if OP is extended 1 inch when a is compressed $\frac{1}{2}$ inch, necessarily, one ton acting to extend the line OP will compress a with a force of two tons, hence writing the proportion as an equation—

$$qx = y \quad . \quad . \quad . \quad . \quad 1^{\circ}$$

The stress on the member a due to H will be qH; and

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similarly, the stress on a due to V will be pV, if we call p the stress which one ton acting upwards at O would produce on a, the frame being held rigidly at P.

The total stress due to V and H acting at once on the member a, will be pV + qH; and as the value of x due to V and H, we have—

$$x = e(p\mathrm{V} + q\mathrm{H}),$$

where e is the compression or extension of the member produced by the unit stress, but by equation 1,

$$y = epq\mathrm{V} + eq^2\mathrm{H} \quad . \quad . \quad . \quad 2°$$

Thus y will be the extension of the abutments, existing simultaneously with the forces V and H acting as described, with the unknown load producing these forces, and with the particular extensibility of the member a due to its length, cross section, and the material of which it is made. But the same quantity y could be calculated for the extensibility due to each member of the frame, and the result would not be altered by the slight yielding of all the others, unless this yielding produced sensible deformation; hence the sum of all the values of y, or the total extension of the abutments, will be

$$\Sigma y = \Sigma(epq)\mathrm{V} + \Sigma(eq^2)\mathrm{H} \quad . \quad . \quad . \quad 3°$$

and if the abutments are perfectly rigid, the value of Σy becomes *nil*, and we have—

$$\mathrm{H} = -\frac{\Sigma(epq)\mathrm{V}}{\Sigma(eq^2)} \quad . \quad . \quad . \quad . \quad 4°$$

If the abutments are not rigid, but yield, calling e_1 the elongation due to unit stress on these abutments, we have—

$$e_1\mathrm{H} + \Sigma epq\mathrm{V} + \Sigma eq^2\mathrm{H} = 0 \quad . \quad . \quad 5°$$

because the total elongation along BC caused by H must be equal and apposite to the total elongation which all the forces in the other members would produce.

From these equations, the horizontal thrust can be calculated for any load producing V, when we know e, p, and q for every member.

The calculation of p and q is a simple matter by the principle of moments, and $e = \frac{l}{\mathrm{EA}}$ where l is the length of

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the given member, A the cross section, and E the modulus of elasticity of the material; thus it is at once seen that the horizontal thrust of a stiff arch, braced or not, does not depend simply on the form and load, but also on the cross section of each member, and when the abutments yield, on the material employed in the frame,—conclusions which are thoroughly in accordance with common sense, but which have been almost wholly neglected in practice.

If the load on a chain were really permanent, no better form could be devised for the chain than that into which it naturally falls; but when the load is sometimes distributed in one way and sometimes in another, the double chain gives perfect stiffness, and calculation proves that the only result of a change in the distribution of the loads is to change the relative tensions or relative compressions of the two members.

The proposal of a double-braced chain for a suspension bridge is not new, though the writer believes that the form proposed on which the lower chain is horizontal is new.

The proposal of double compression members for an arch is perhaps quite new, though analogous to the double-braced chain of the suspension bridge.

No one, however, appears to have perceived, nor could they perceive, until the calculations were carried out, what would be the most economical distribution of material in the two chains, much less in the two compression members.

The two chains have hitherto been made equal to one another, being, in fact, looked upon as two separate bridges, each carrying half the weight, the bracing between them being analogous to the stiffening girder; and where a single chain has been braced to the flooring, no attempt, as the writer believes, has been made to ascertain what would be the best distribution of material.

The new calculation shows, that for a uniform load the chain of a braced suspension bridge, of the form in fig. 1, should be tapered at the middle to nearly one-tenth its cross section at the pier; and the bottom member, also wholly in tension, should be increased in the ratio of 1 to 8 from the piers to the centre, where it should have nearly the cross section of the top chain at the pier.

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An arch designed on such a plan as this would be a still greater novelty, but the design would be equally correct.*

This distribution of material, slightly modified to meet practical requirements, has been patented by the writer.

In the appendix, the calculations required to determine the stress on each member of the given type of framed arch, shown in fig. 1, are given at some length. These calculations are tedious, but present no difficulty if made in a methodical manner.

The first process in the calculations was to determine by equation 4 the horizontal thrust due to the load on each top joint. These thrusts are given in Table VI.

Then with each of these horizontal thrusts and corresponding loads, the strains on each member of the bridge have been determined by the graphic methods represented in figs. 6 to 14.† From the strains thus determined, the maximum strains on each member are selected and written on the corresponding member, diagram 15 in black figures.

From fig. 6 the strains for a uniform load of 240 tons have been taken, and are written on the diagram in red.

The calculations prove the possibility of constructing a suspension bridge which shall be as stiff as a girder without any compression member, except some light diagonal shafts, and show that a framed arch might be constructed stable under unsymmetrical loads — both arch and suspension bridge being much lighter than the equivalent girders.

To prove this, we may follow the plan adopted by Mr Bramwell ("Proceed. I. C. E.," vol. xxii. p. 560) in comparing American and English trusses.

Assuming that the bridges are made of equally good materials, and that the same coefficient of safety be used, the weight of each truss will be proportional to the sum of the products of the lengths of each member by the maximum strain which comes upon it, the cross section being assumed proportional to this strain. Now, taking a simple triangular girder 120 feet span (fig. 2), 12 feet deep—a

* Since writing the above, the author has found a drawing in one of Weale's Papers in which a wooden arch is designed on some such plan.

† *Vide* Trans. Roy. Soc. Edin. vol. xxv. p. 441, "On the Practical Application of Reciprocal Figures to the Calculation of Strains on Framework."

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rather excessive depth—the sum of the products of the maximum strains due to a permanent load of 1 ton per foot run, and a passing load of 1 ton per foot run, is 69,700, as compared with 39,466 for a framed arch (fig. 1) 120 feet, a rise of 12 feet, and a depth of 5 feet at the crown. The same product for a bowstring girder 17 feet deep at the centre is 60,890 (fig. 3).

FIG. 2.

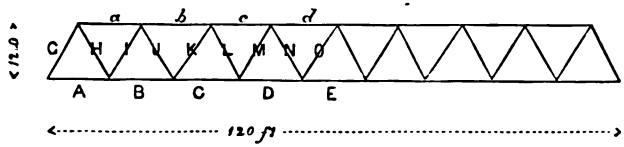
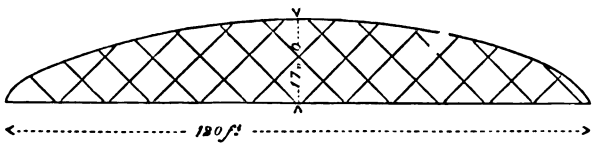


FIG. 3.



Figs. 4 and 5 represent graphically the relative quantity and distribution of material required in trusses of the two types shown in figs. 1 and 2. The breadth of each member in figs. 4 and 5 is proportional to the cross section required, and the sum of the areas enclosed by the lines bounding these members thus drawn, is proportional to the whole quantity of material required in the two types. The ratio of the areas is 70 to 40, roughly.

The above figures or numbers represent fairly the relative values of the several forms for moderate spans where the bulk of the weight is due to the passing load and to the roadway. It must, however, be remembered that the arch and suspension bridge require solid abutments or anchorage, which, in many cases, would leave the girder the cheaper of the two constructions; but when large spans are necessary, a great part of the weight is due to the supporting truss itself, and then the above figures fall short of expressing the relative efficiency of the old and new forms.

The following calculation gives the limiting spans beyond which each form of truss would not carry its own weight without straining the material employed beyond a fixed

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limit, and this limit forms a convenient constant by which to calculate the theoretical weight of any truss of smaller span, but similar in form, and required to carry any given load.

From the numbers 69,700 for the girder, 60,890 for the bowstring, and 39,466 for the framed arch, we can at once determine the theoretical weight of a 120 feet truss of each form, assuming the material to be wrought iron and the limiting strain 4 tons.

The above numbers are a product of feet into tons, so that dividing by 4, we obtain the products of the total length in feet of the members into their cross section in square inches, and dividing again by 665, the length of a rod of iron in feet of 1 inch cross section, and weighing 1 ton, we obtain the theoretical weight of each truss, on the assumption that no material whatever is wasted in joints, rivets, &c.

TABLE I.

Showing the probable weights of trusses, of various types, to carry 2 tons per foot run, uniformly distributed over a span of 120 feet.

1°	2° Strain.	3° Weight in tons if no metal were wasted.	4° Practical weight in tons, adding 25% for waste. = B.	5° Constant C, $= \frac{WL}{B}$.
Girder, wrought iron, 12 feet deep, . .	4 tons per sq. inch.	26·2	33	873
Bowstring, wrought iron, 17 feet deep at centre, . . .	4 tons per sq. inch.	22·9	28·6	1007
Framed arch, wrought or cast iron, 12 ft. rise, 5 ft. deep at crown; or suspension bridge, same dimensions, but of wrought iron, . .	4 tons per sq. inch.	14·7	18·4	1565
Framed arch, wood, 12 ft. rise, 5 ft. deep at crown, wood to weigh 40 lbs. per cubic foot, . . .	5 cwt. per sq. inch.	19·4	24·3	1180
Suspension bridge, steel rope, 12 ft. deep, 5 ft. deep at crown, . . .	8 tons per sq. inch.	7·35	9·2	3130

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Column 3° in the Table I. gives these weights for each form. These weights must practically be increased about 25 per cent. to allow for necessary excess of material due to joints and rivets. This practical weight, B, is given in column 4°. But calling L the span, and W the total load which a truss will bear, the ratio, $\frac{B}{W}$, will be constant for a given span, and will bear a constant ratio to the span, so long as the construction and materials and proportions are unaltered; that is to say, we have—

$$\frac{B}{W} = \frac{L}{C},$$

where C is a constant for each type of truss.

In the above table we have W = 240 tons, and hence we can calculate C, the constant, which is given in column 5°. When B = W, *i.e.*, when the beam can only (with the coefficient of safety chosen) carry its own weight, we have C = L, *i.e.*, the constant is equal to the limiting span in feet.

The numbers in the column 5°, therefore, give the limiting spans for each form, with the strains indicated in the table. These spans could not be used in practice, because bridges are required to carry a passing load, and not their own weight only. To fix the practically useful spans, we may choose what proportion of the metal in the truss shall be available to carry a passing load after providing enough to carry the whole truss; in other words, what the proportion is to be between the passing and permanent loads.

If we determine that these two loads are to be equal, we have $\frac{B}{W} = \frac{L}{C} = \frac{1}{2}$, and the limiting useful spans of each form are equal to $\frac{C}{2}$, showing that even under these conditions a framed cast iron or wrought iron arch might be constructed for a span of 790 or 800 feet, and that its weight need not exceed 800 tons to carry a gross load of 1600 tons uniformly distributed. If instead of fixing the ratio between passing and permanent load, we fix the passing load and useless weight at, say 1·4 ton per foot run, and then seek to find

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the necessary weight of truss for each form and span, we may conveniently make the calculation by the formula given in Rankine's "Applied Mechanics," § 314. The relative weight thus calculated for trusses of the three different types adopted, is given in Table II. for spans varying from 200 feet to 2000 feet, the ratio between the spans and depths remaining constant. The gain of the arch over the girder is far more conspicuous in the large than in the small spans. Thus, while for a 200 feet span the weight of the girder is only double that of the arched truss, for a 600 feet span the arch weighs only about one-quarter as much as the girder. An arch of 700 feet span need not weigh more per foot run than a girder of 400 feet span.

The arch of 500 feet span need only weigh 0·65 tons per foot run; whereas the Britannia Bridge girder weighed about 3·8 tons per foot run; a light girder might be made to weigh about 1·88 tons per foot run.

TABLE II.

Showing weight in tons of the different types of trusses, assuming that the girders and arches are strained to 4 tons per square inch only, that the passing load to be carried is 1·4 tons per foot run, and that the practical weight is 25% in excess of the minimum possible weight, if no metal were wasted.

Span.	Weight of wrought iron Girder, in tons.		Weight of wrought iron Bowstring, in tons.		Weight of wrought iron Suspension Bridge, and wrought iron or cast iron Arch, in tons.		Weight of Wooden Arch, in tons.		Weight of Suspension Bridge, in tons. Strain, 8 tons per square inch.	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Feet.	Total.	Per ft. run.	Total.	Per ft. run.	Total.	Per ft. run.	Total.	Per ft. run.	Total.	Per ft. run.
200	83	·415	70	·35	41	·205	57·1	·285	19	0·095
300	222	·74	180	·60	100	·33	142	·473	45	0·15
400	475	1·19	375	·94	194	·485	285	·712	83	0·207
500	940	1·88	700	1·4	330	·65	510	1·02	134	0·268
600	2,220	3·7	1260	2·1	530	·883	870	1·45	200	0·333
700	3,900	5·57	2290	3·27	790	1·13	1440	2·06	280	0·400
800	12,800	16·	4450	5·56	1180	1·475			384	0·48
1000					2490	2·49			655	0·655
1200					5600	4·67			1060	0·885
1400									1580	1·128
1600									2360	1·475
1800									3410	1·89
2000									4950	2·475

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There would be no difficulty in making the braced arch of cast iron in simple pipes, and the cost of the superstructure of such a span would be about one-sixth that of a wrought iron girder, one-third the material being required, and the material only half as expensive.

With suspension bridges it would be absurd to limit the strain to 4 tons per square inch, and taking double this as a fair strain for wire ropes, the limiting span would be 1600 feet, even if the ropes weighed as much as the passing load, and this were required to be 1 ton per foot run over the entire length. The weights of trusses for various spans to carry 1·4 tons in addition to their own weight are given in Table II., from which it will be seen that for the span of 2000 feet the ropes need not weigh more than 2·5 tons per foot run, and the theory which has been explained shows that with this weight the suspended frame would be rigid and as well adapted for railway traffic as the tubular girder. When these facts are known, it seems impossible to doubt that large spans will become common, so as to dispense with piers, and that the framed arch and suspension bridge will in many cases supersede the girder.

With wood the results are not less remarkable. Assuming 5 cwt. as the working strain per square inch, the weight of a framed arch of 120 feet per span, to carry 2 tons per foot run, would be only about 24·3 tons, giving for C a value of nearly 1180.

In the superstructure of such an arch only about 1400 cubic feet of timber would be wanted, and the wood could be used in rough balks, with the ends simply abutting against each other. With light iron ties and wooden struts between the top and bottom members, an exceedingly cheap bridge could be made either for permanent or temporary use. In the latter case the timber would not have been injured by being cut into unserviceable dimensions.

When a series of arches are designed care must be taken to provide for the thrust of a loaded arch on its unloaded neighbour. In small spans this unbalanced thrust may throw the top member of the unloaded arch into tension,

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but in large spans it will generally only relieve the top member of part of the compression due to the permanent load, without increasing the compression on the bottom member beyond that due to the passing permanent load combined.

In the framed arch there are no parts exposed to any considerable tension, a point of great practical importance in all materials, but especially in wood.

It should be observed that the calculations are all based on the assumption that no horizontal force is to be applied at the abutments, except such as results from the load on the bridge. If the bridge weighed nothing, the dimensions of the frame and the opening of the span are to be such that the value of H would be *nil*. The frame must be neither jammed nor extended by any external independent force. In the erection of these trusses regard must be had to this condition, which will require special precautions to be taken where centering or other independent supports are not used while the truss is being erected. Care must also be taken that in a suspension bridge the suspension at the piers is such as not of itself to determine the direction of the resultant.

It is essential that, in calculations referring to the framed arch, we should be able to take into account the influence of temperature, or of a yield in the abutments, to which a given compression in the material may be conceived as precisely equivalent. The yield of the abutments d is precisely what in equation 3° has been called Σy. Hence calling H_1 the thrust with a yield d, we have—

$$d + \Sigma(epq)V + \Sigma(eq^2)H_1 = 0\,,$$

or

$$H_1 = -\frac{d + \Sigma(epq)V}{\Sigma(eq^2)} \quad . \quad . \quad . \quad 6°$$

and

$$H_1 = H - \frac{d}{\Sigma(eq^2)} \quad . \quad . \quad . \quad 7°$$

The change in the horizontal thrust of the arch is therefore determined when we have determined arbitrarily or by

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calculation the quantity d, and know the value of e for a given material. For our typical arch we found—

$$\Sigma \frac{q^2 l}{S} = 11{\cdot}313\,,$$

hence

$$\Sigma(eq^2) = \frac{11{\cdot}313 \times 12}{E}\,,$$

where E is the modulus of elasticity of the material, the factor 12 being introduced, inasmuch as in our tables the length of the members has been taken in feet, while their cross section was in square inches.

For wrought iron

$$E = 1300\,,$$

hence

$$\Sigma(eq^2) = 0{\cdot}0104\,;$$

and if we assume

$$d = 0{\cdot}104 \text{ feet},$$

then

$$\frac{d}{\Sigma(eq^2)} = 10 \text{ tons},$$

or less than 5 per cent. of the maximum thrust where the arch was loaded with 240 tons. In cast iron, the change would be about half the above, and in wood still less. Temperature would cause a considerably less change in relative dimensions of truss and span than the tenth of a foot assumed in 120 feet.

These calculations show that the flexibility of the frame is such, with reference to extension or compression in the line of the abutments, that little is to be feared in most cases, either from a change of temperature or a yield in the abutments, when the truss is finally closed. An allowance for the change of distribution in the strains on a suspension bridge would have to be made where the anchorage chains are long and subject to considerable elongation or contraction from changes in temperature, and the equations show exactly how an allowance can be made for any assumed conditions of elasticity and change of temperature.

The paper when read was illustrated by three models—one being the ordinary flexible suspension bridge ; a second,

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in which a framed suspension bridge, with wire for top and bottom members, was shown to be stiff under any practical distribution of load; a third, showing a framed arch of timber, in which the top and bottom members butted against each other, but were not held together by any tie. This model was also loaded unequally, so as to show that, with all practical distributions of load, both top and bottom members were in compression.

APPENDIX.

Detailed Calculations.

These laborious calculations were chiefly carried out by Mr Charles Hockin, to whom the thanks of the writer are due.

1*st*, Span of bridge, 120 feet; versine, 12 feet; depth at crown, 5 feet; radius, 156 feet.

The first thing to be calculated is the value of the strain on each member of the bridge due to a force at the abutments acting horizontally. Call the strain on any beam due to such force, when equal to one ton, the "q" for that beam. The values of q are as under; the letters giving the names of the beams or numbers refer to fig. 1.

The letters having the fig. 1 subjoined, refer to those members of the frame which are symmetrical with the members bearing the same unmarked letter.

TABLE III.—*Values of q.*

Name of Beam.	Value of q.	Name of Beam.	Value of q.	Name of Beam.	Value of q.	Name of Beam.	Value of q.
a	− 0·27183	A	+ 1·2032	G	− 0·444	H	+ 0·450
b	− 0·63901	B	+ 1·5198	I	− 0·478	J	+ 0·480
c	− 1·1172	C	+ 1·9267	K	− 0·500	L	+ 0·502
d	− 1·67765	D	+ 2·42685	M	− 0·484	N	+ 0·488
e	− 2·1850	E	+ 2·9417	O	− 0·384	P	+ 0·386
f_1	− 2·4000	F	+ 3·2934	Q	− 0·153	R	+ 0·154
e_1	− 2·1850	F_1	+ 3·2934	Q_1	− 0·153	R_1	+ 0·154
d_1	− 1·67765	E_1	+ 2·9417	O_1	− 0·384	P_1	+ 0·386
c_1	− 1·1172	D_1	+ 2·4268	M_1	− 0·484	N_1	+ 0·488
b_1	− 0·63901	C_1	+ 1·9267	K_1	− 0·500	L_1	+ 0·502
a_1	− 0·27183	B_1	+ 1·5198	I_1	− 0·478	J_1	+ 0·480
		A_1	+ 1·2032	G_1	− 0·444	H_1	+ 0·450

We must next calculate the value of the strain on each beam due to a force at the abutments acting vertically.

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Call p the strain on any beam due to a force of one ton acting vertically at the left abutment, this force being balanced by rigidity at the right abutment.

TABLE IV.—*Values of p.*

Name of Beam.	Value of p.	Name of Beam.	Value of p.	Name of Beam.	Value of p.	Name of Beam.	Value of p.
a	+ 0·71807	A	− 0·35389	G	+ 1·173	H	− 1·189
b	+ 1·87175	B	− 1·3410	I	+ 1·505	J	− 1·780
c	+ 3·6622	C	− 2·8334	K	+ 1·872	L	− 1·8795
d	+ 6·2263	D	− 4·9965	M	+ 2·214	N	− 2·2325
e	+ 9·3194	E	− 7·78695	O	+ 2·341	P	− 2·353
f	+ 12·0000	F	− 10·6552	Q	+ 1·9075	R	− 1·920
e_1	+ 13·1628	F_1	− 12·5925	R_1	+ 0·8329	Q_1	− ·8275
d_1	+ 12·67475	E_1	− 12·9783	P_1	− 0·3713	O_1	+ ·3694
c_1	+ 11·2827	D_1	− 12·1343	N_1	− 1·212	M_1	+ 1·202
b_1	+ 9·6978	C_1	− 10·7670	L_1	− 1·657	K_1	+ 1·664
a_1	+ 8·2596	B_1	− 9·3869	J_1	− 1·876	I_1	+ 1·880
		A_1	− 8·1395	H_1	− 1·367	G_1	fixed.

TABLE V.

Assumed cross sections of each member, being numbers approximately proportional to the maximum strains due to the thrusts which had been previously calculated for members of uniform cross section, with a uniform load of 10 *tons on each joint, and a passing load of* 10 *tons on each joint.*

Name of Member.	Cross Section = S.	Name of Member.	Cross Section = S.	Name of Member.	Cross Section = S.
a or a_1	20	A or A_1	220	G	
b or b_1	50	B or B_1	200		
c or c_1	80	C or C_1	170		
d or d_1	130	D or D_1	130	to	50
e or e_1	180	E or E_1	80		
f	200	F or F_1	50	G_1	

Since in the formula,

$$H = \frac{V\Sigma(epq)}{\Sigma(eq^2)}$$

the value of e (the elongation or compression due to the unit stress on each bar) appears for each bar both in the numerator and denominator, any factor common to the value of e for every bar may be omitted without affecting the result. The modulus of elasticity of the material is a factor of this kind, and for e we may therefore substitute $\frac{l}{S}$, where l is the length in feet and S the cross section in

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inches, since the total elongation or compression of each bar will be proportional to $\frac{l}{S}$ with the unit stress on any constant material. Hence, instead of finding the values of $\Sigma(eq^2)$ and $\Sigma(epq)$, we shall seek for the values of $\Sigma\frac{l}{S}q^2$ and $\Sigma\frac{l}{S}pq$.

TABLE VI.

Giving partial results of the calculation of $\frac{q^2l}{S}$.

1. Name of Member.	2. $\frac{q^2l}{S}$	3. Name of Member.	4. $\frac{q^2}{S}$	5. Name of Member.	6. q^2l
a	0·03695	A	0·006581	G and G_1	3·493
b	0·08786	B	0·011549	H „ H_1	2·689
c	0·15602	C	0·021837	I „ I_1	2·977
d	0·21650	D	0·045305	J „ J_1	2·714
e	0·26522	E	0·108170	K „ K_1	2·819
f	0·28800	F	0·216935	L „ L_1	2·464
e_1	0·26522	F_1	0·216935	M „ M_1	2·145
d_1	0·21650	E_1	0·108170	N „ N_1	1·995
c_1	0·15602	D_1	0·045305	O „ O_1	1·148
b_1	0·08786	C_1	0·021837	P „ P_1	1·116
a_1	0·03695	B_1	0·011549	Q „ Q_1	1·677
		A_1	0·006581	R „ R_1	1·676
		$\Sigma^{A}_{A_1}\frac{q^2}{S}$ =	0·820754	$\Sigma^{G}_{G_1}q^2l$ =	53·826
$\Sigma^{a}_{a_1}\frac{q^2l}{S}$ =	1·81309	$\Sigma^{A}_{A}\frac{q^2l}{S}$ =	8·42321	$\Sigma^{G}_{G_1}\frac{q^2l}{S}$ =	1·0765

The sum of column 4° is multiplied by the constant length, 10·262772. The sum of column 6° is divided by the constant cross section, 50.

$$\Sigma\left(\frac{q^2l}{S}\right) = 1{\cdot}81309 + 8{\cdot}42321 + 1{\cdot}0765 = 11{\cdot}313\,.$$

In calculating the values of $\frac{lpq}{S}$ as in those of $\frac{lq^2}{S}$, since some numbers have a constant length, and others a constant cross section, it is convenient to treat the arch, boom, and bracing separately. The sums of $\frac{lpq}{S}$ have to be multiplied by V, the vertical component of the weight on the

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piers, and this component varies of course with each position of the load.

In order to calculate the value of V $\Sigma \frac{lpq}{S}$ for any given load, we must sum up $\frac{lpq}{S}$ for all the members to the right and to the left of the load separately, since these sums will have to be multiplied by different values of V; to allow us to do this, the columns headed Σ are calculated, and contain the values of the sums of the first two, the first three, &c., values of $\frac{pq}{S}$ or pql, as the case may be.

TABLE VII.

All the values in this table are negative except the two marked +.

1. Name.	2. $\frac{pq}{S}$	3. Σ	4. Name.	5. $\frac{pq}{S}$	6. Σ	7. Name.	8. pql.	9. Σ
a	0·009760	·009760	A	·001935	·001935	G	9·229	9·229
b	0·024811	·034572	B	·010190	·0121255	H	7·106	16·335
c	0·051143	·085714	C	·032113	·044238	I	9·357	25·692
d	0·080350	·166064	D	·093275	·137513	J	10·064	35·756
e	0·11312	·27918	E	·28634	·42385	K	10·553	46·309
f	0·14400	·42318	F	·70184	1·12569	L	9·228	55·537
e_1	0·15978	·58296	F_1	·82945	1·95514	M	9·817	65·354
d_1	0·16357	·74653	E_1	·47723	2·43237	N	9·129	74·483
c_1	0·15756	·90409	D_1	·22652	2·65889	O	7·002	81·485
b_1	0·12855	1·03264	C_1	·12203	2·78092	P	6·802	88·287
a_1	0·11226	1·14490	B_1	·071330	2·85225	Q	2·082	90·369
			A_1	·044516	2·89677	R	2·091	92·460
						R_1	+0·9069	91·553
						Q_1	+0·9033	90·650
						P_1	1·0734	91·723
						O_1	1·005	92·728
						N_1	4·956	97·684
						M_1	5·330	103·024
						L_1	8·136	111·150
						K_1	9·381	120·531
						J_1	10·602	131·138
						I_1	11·688	142·826
						H_1	8·168	150·994

In order to calculate the value of V. $\Sigma\left(\frac{lpq}{S}\right)$ for any given load, the values of the sums for members a to a, must be multiplied by the correct length; for members A to A, must be multiplied by the constant length 10·263; and for members G to G, must be divided by the constant cross section 50.

Now, the sums of all these numbers to the right and to

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the left of each load must be made separately, and each sum multiplied by the portion of the load borne by the piers to the right and to the left respectively, these fractions being the special values of V for that particular load. In this way we form Table VIII., giving the values of the sums for the load on each joint—the factor 24 being introduced for convenience of calculating the loads on each pier.

TABLE VIII.

Values of $\Sigma \frac{pql}{S} V \times 24$ *for unit load on each joint.*

Load on first joint =

$$23(0 + \frac{9{\cdot}229}{50} + 0{\cdot}001935 \times 10{\cdot}262772)$$
$$+ 1(1{\cdot}1449 \times 10 + \frac{150{\cdot}994}{50} + 2{\cdot}85225 \times 10{\cdot}262772) = 48{\cdot}443.$$

Load on second joint =

$$21(0{\cdot}00976 \times 10 + \frac{25{\cdot}692}{50} + 0{\cdot}034571 \times 10{\cdot}262772)$$
$$+ 3(1{\cdot}03264 \times 10 + \frac{131{\cdot}138}{50} + 2{\cdot}78092 \times 10{\cdot}262772) = 139{\cdot}93.$$

Col. 1. Joint Loaded.	Col. 2. $\Sigma \frac{pql}{S} \times 24$ for One Ton on each Joint.	Col. 3. Horizontal Thrust H, for each single Load of Ten Tons on Joint named in Col. 1.	Col. 4. Passing Load added to uniform Load of Ten Tons on each Joint.	Col. 5. H, with Distribution of Load in Col. 4.
1	48·443	1·780	10 tons on first joint.	111·166
2	144·757	5·158	10 tons on 2 first joints.	116·324
3	225·911	8·3193	10 tons on 3 do.	124·643
4	301·839	11·116	10 „ 4 „	135·759
5	364·817	13·436	10 „ 5 „	149·195
6	404·118	14·884	10 „ 6 „	164·079
7	404·118	14·884	10 „ 7 „	178·963
8	364·817	13·436	10 „ 8 „	192·399
9	301·839	11·116	10 „ 9 „	203·515
10	225·911	8·319	10 „ 10 „	211·834
11	144·757	5·158	10 „ 11 „	216·992
12	48·443	1·780	10 „ 12 „	218·772
Thrust H, with all joints loaded with 10 tons,		109·386	10 tons on 4 middle joints.	166·026
			10 tons on 6 do.	188·258
			10 „ 8 „	204·896

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Column 2° having been obtained as explained above, column 3° is got by multiplying the values in column 2° into 10, the value of the load of each joint, and dividing the product by 24, the arbitrary factor, and by 11·313, the value of $\Sigma \frac{q^2 l}{S}$ obtained from Table IV.

The thrust of any combination of loads is obtained by adding the thrust due to each load separately calculated.

Thus the value of H for the uniform load of 10 tons on each joint is obtained by adding up column 3°.

Column 5° is obtained by adding to 109·386 the appropriate thrust or thrusts taken from column 3° to correspond with the loads named in column 4°.

With the values of H in column 5° the reciprocal figures 6 to 14 were constructed to determine the stresses on each member, and Table IX. contains the result of the calculation.

The stresses thus calculated are not far from proportional to the assumed cross sections calculated by a similar process for a uniform cross section throughout; it is therefore unnecessary to aim at any closer approximation by repeating the calculations with new assumed cross sections.

TABLE IX.

Stresses calculated by the graphic method, due to a uniform load of 20 *tons on each of the upper joints, and maximum stresses due to uniform load of* 10 *tons on each joint, and an equal passing load.*

Name.	Strain with uniform Load.	Maximum due to passing Load.	Name.	Strain with uniform Load.	Maximum due to passing Load.	Name.	Strain with uniform Load.	Maximum due to passing Load.	Name.	Strain with uniform Load.	Maximum due to passing Load.
a	20	24	A	220	220	G	44	51	H	−24	−31
b	49	56	B	188	193	I	49	53	J	−28	−32
c	88	94	C	148	159	K	53	54	L	−30	−32
d	135	138	D	101	120	M	53	55	N	−29	−30
e	177	177	E	54	74	O	45	53	P	−19	−23
f	195	195	F	23	33	Q	27	36	R	− 1	−19+21

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Sum of products of length into maximum stress:—

Top members,	11,330	For uniform load.		11,730	For maximum strains due to passing load.
Bottom members,	15,065			16,399	
Struts,	6,442			* 7,689	
Ties,	2,610			* 3,648	
Sum,	35,447		Sum,	39,466	

The two last sums are the sums of the products of the stresses on the members in tons multiplied into the length in feet.

TABLE X.

Stresses on a triangular-framed girder of nine bays, 120 feet span, 12 feet deep, loaded at the top uniformly with 26·67 tons on each apex, being 1 ton per foot run, and also with 13·33 tons on each apex, and an equal passing load. (Fig. 2.)

Name.	Strain with uniform Load.	Maximum due to passing Load.	Name.	Strain with uniform Load.	Maximum due to passing Load.	Name.	Strain with uniform Load.	Maximum due to passing Load.	Name.	Strain with uniform Load.	Maximum due to passing Load.
a	116	116	A	67	67	G	137·5	137·5	H	106·5	114
b	207	207	B	170	170	I	106·5	114	J	76	92
c	267	267	C	214	244	K	76	92	L	45	69
d	296	296	D	289	289	M	45	69	N	14	46
			E	304	304	O	14	46			

Bottom members,	24,617	Bottom members,	24,617
Top members,	23,656	Top members,	23,656
Struts and ties,	17,053	Struts and ties,	21,436
	65,326		69,709

Bowstring girder 120 feet span, 17 feet deep at centre.
Uniform load of 240 tons.
Strains on top member nearly uniform, 212 tons.
Strains on bottom member nearly uniform, 212 tons.

Product for bottom members,	25,440
Product for top members,	27,750
Assume one-sixth for diagonals,	8,700
	60,890

* The stresses on the ties are taken as uniform at 32 tons: on struts as uniform at 55 tons.

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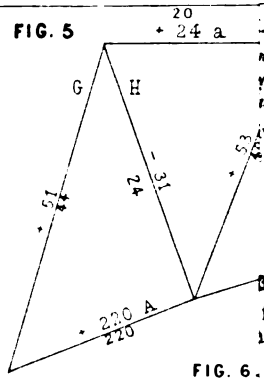
FIG. 5



AGRAMS OF STRESSES

nsion Bridge 120 ft. Span, 12 ft. Rise or Dip, and 5 ft. deep at Centre,
h proportional to Maximum Stresses, the load being 10 tons
int, with a passing load of 10 tons on each Top Joint.

ive the maximum stress with any distributions of load.
the stress when the truss is uniformly loaded with
20 tons on each joint.

FIG. 6.

Uniform load of 2
on each joi

first eight joints
aining joints

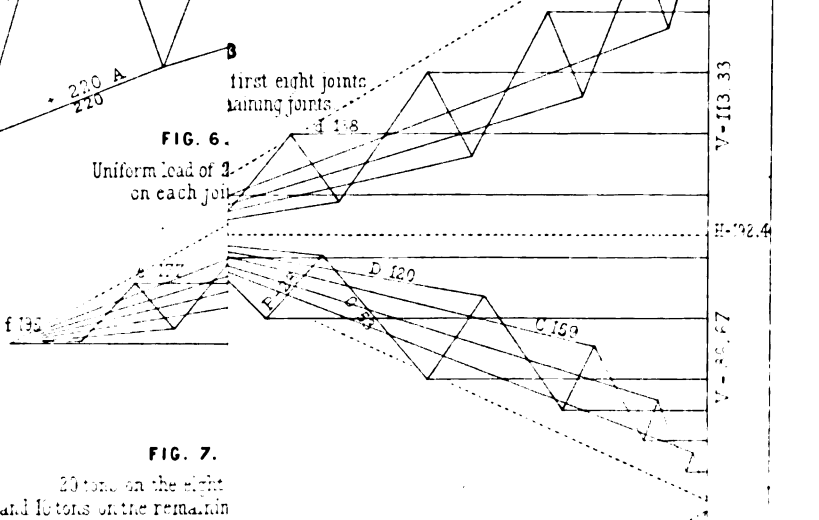


FIG. 7.

20 tons on the eight
and 10 tons on the remainin

FIG. 14.

20 tons on the first ten joints
tons on the remaining joints.

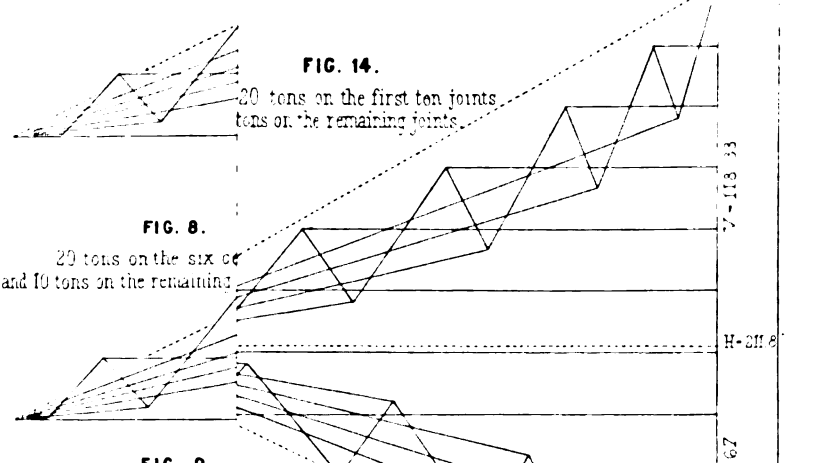
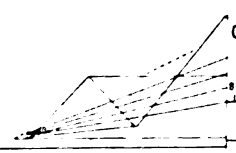


FIG. 8.

20 tons on the six c
and 10 tons on the remaining

FIG. 9.

20 tons on the four
and 10 tons on the remain



0 FEET, 1 INCH.

DIAGRAMS.

80 90 100 110 120 130 140 150.

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FIG. 4.

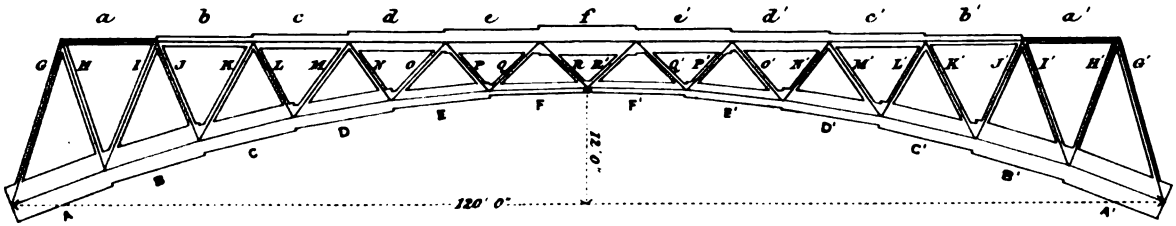
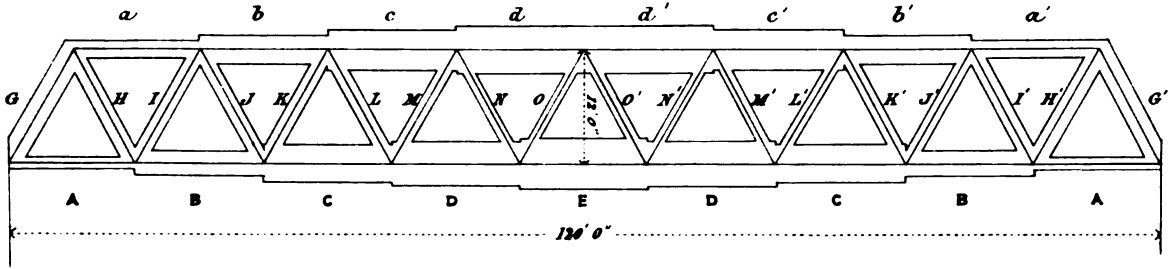


Diagram showing the relative quantity and distribution of material in a framed arch and lattice Girder.

FIG. 5.



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The Ballot-Register: A Mechanical Balloting Apparatus for Parliamentary and Municipal Elections. Designed by JAMES DAVIE, Printer, Edinburgh.*

In submitting the design of the Ballot-Register to the members of the Royal Scottish Society of Arts, it is unnecessary to advert to the expediency of adopting the ballot as an electoral agency. Public opinion is daily widening in its favour for that purpose, and it is evident that a trial of the ballot must be made. Along with the desire for the introduction, there is much distrust, however, of the modes of balloting in use in those countries where it is employed in elections of representatives, and there is consequently a strong hope that a mode combining all the requisites of a thorough ballot may be devised. Several projects, accordingly, more or less distinct in their principles from each other, have been put forth during the past year; and to the design of one of these your attention is now solicited.

The essentials of the ballot to be secured, and to embody which has been the aim in designing the Ballot-Register, are,—*Secrecy, Privacy, Impracticability of Fraud, Simplicity of Action,* and *the certainty that the vote recorded is given to the party for whom it is meant.* The principle consists in *one and the same ball* being used by all the electors of a voting district consecutively,—the one ball acting as the recording agent for each voter by *printing* his vote, or a mark equivalent to his vote, on the recording sheet within the apparatus; the ball immediately thereafter each vote returning to the sheriff's desk to be used by the next in succession. By this means each voter *for himself* is enabled to record his vote in the columns of the recording sheet (by a mark similar to those placed against the voter's names under the present system of elections), in a secret, safe, and legible manner; and while enabled to effect this, it is not in his power to do more than he is entitled to perform.

The Ballot-Register complete consists of an enclosed

* Read before the Society 10th January 1870, and awarded the Society's Silver Medal and Plate, value Three Sovereigns.

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chamber 4 feet square by 7 feet in height, having two doors —entrance and exit, opposite to each other, each shutting closely by spring hinges, light being admitted by the top through obscured glass. In the interior of the chamber on one side, and occupying its full width, is a box about one foot in depth and breadth, containing the voting apparatus, and bearing on its lid a range of coloured cups. These cups are numbered 1, 2, 3, &c., and have also the names of the candidates attached to whom each has been appropriated.

On a voter being accredited, he is presented by the sheriff with a metal ball about one inch diameter, with which he enters the ballot-chamber by the entrance door. When in the chamber the voter's sole duty is to place the ball he has received into the cup of the candidate he means to vote for, and pass out by the opposite or exit door.

The essentials stated as necessary in a ballot are secured in the Ballot-Register as follows:—

1. *Secrecy* and *Privacy.*—The ballot-chamber is entirely enclosed, and no voter can pass into the chamber until the sheriff has given him the voting ball to deposit. As the ball cannot pass back to the sheriff's desk till the preceding voter has recorded his vote and is leaving the chamber, the succeeding voter cannot intrude upon the former's privacy.

2. *Impracticability of Fraud.*—By using one ball only for all the electors of a district, there is no opportunity for fraud, and as the recording apparatus is locked up, there is no possibility of tampering with it.

3. *Simplicity of Action.*—The action on the part of the voter is exceedingly simple; there is no exercise of judgment or memory required other than to select a candidate's cup and place the voting ball in it. The mechanism, also, is simple in its details, and of a nature little liable to go wrong or requiring skill to rectify.

4. *Suitability for more than one Member.*—By using *two* balls if two members, or *three* balls if three members are wanted, the Ballot-Register requires no other adaptation.

The recording sheet being diced into squares, each square containing one vote only, the enumeration of the recorded votes will not be difficult. A ballot-chamber 4 feet square

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allows voting capacity for six candidates, and a cylinder 6 inches diameter can give recording space for 3000 voters, whether for one, two, or three members. On publishing the names of candidates for election, if nomination is to be superseded, were a number and colour attached to each, as here employed, with a voting medium such as the Ballot-Register, the most ignorant could scarce fail to distinguish in the ballot chamber where he should deposit the voting ball, without interference or supervision by any one. The opening of entrance and exit doors properly placed are almost natural motions and understood by all, and as these openings in the Ballot-Register effect all the working of the mechanism, what is left for the voter to perform can hardly be made simpler or more secure against fraud, in any method of vote by ballot.

Description of the Ballot-Register.

The Ballot-Register consists of a chamber of wood or other material, entirely enclosed, 4 feet square by 7 feet in height, roofed with obscured glass, and having two spring-hinged doors placed opposite to each other. Inside the chamber, and occupying one side, is a box about 1 foot in depth and breadth, having on its lid coloured cups, numbered and labelled. The mechanism within the box consists of a cylinder 38 inches long by 6 inches diameter, a toothed wheel being attached at one end—the teeth projecting beyond the diameter of the cylinder. A spindle 43 inches long passes through the centre of the cylinder lengthways, about 8 inches of one end forming a screw, into which a nut fixed at the other end of the cylinder fits. When the spindle is fixed between the end walls of the box, the cylinder revolves and traverses on and along the spindle by means of the screw and nut. The cylinder is covered with a sheet of paper divided into numbered spaces corresponding to the cups on the lid of the box, and forms the recording sheet, a sheet of carbonised paper as the printing medium being placed above it all round.

At one end of the box, and beneath the cylinder, is placed a long pinion with leaves corresponding to the toothed wheel

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on the cylinder, and into which it works, having at its outer extremity a star-like wheel. One tongue of this star-like wheel projects beneath the outside of the bottom of the box.

Above the cylinder, and centred to the cups, are placed steel types. There is one for each cup, and all are suspended on an elastic card to bear their points off the cylinder.

Immediately beneath the inside of the lid of the box, and in line with the cups, and forming the bottoms of the cups, is a thin strip of wood or metal, pierced with holes corresponding in number to the cups outside.

The entrance door has attached to it a lever which, when the door is opened by the voter, pushes forward the projecting tongue connected with the pinion. The cylinder by this action moves forward a space equal to one tooth of the wheel,—the shutting the door restoring the lever to its rest without pressing back the pinion-tongue. Passing to the front of the box the voter places the ball in a cup. While doing so the bottoms of the cups are closed, so that the ball when put in can be shifted to another cup if wished. Leaving the ball in the cup selected, the voter retires by the exit door, the opening of which displaces the bottoms of the cups, bringing the holes in the strip of wood or metal beneath the cups, and allowing whatever is in them to drop through. The ball in dropping falls on the head of the type placed beneath the cup in which the ball was placed, and by its weight impresses the type's point upon the recording sheet on the cylinder. The ball falls off the type-head to an inclined groove leading to the outside of the ballot-chamber at the sheriff's desk, for the use of the next voter. The closing of the exit door restores the bottoms to the cups.

Description of the Atmometro-Hygrometer. By Peter Stevenson, Philosophical Instrument Maker, 51 George IV. Bridge.*

This instrument is designed to give in a simple, accurate, and practical form, all the information desirable as to the

* Read before the Society 24th January 1870, and awarded the Society's Silver Medal and Plate, value Three Sovereigns.

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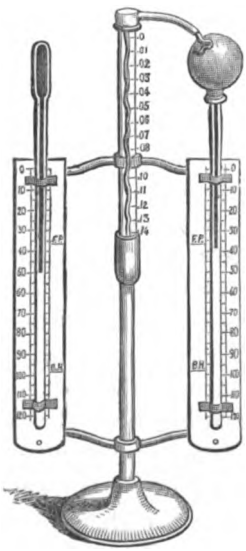
temperature and moisture of the atmosphere, and also the rate of evaporation from any wet or humid surface. It consists of a combination of two instruments—1*st*, The wet and dry bulb thermometers, or what is known as Mason's Hygrometer; and, 2*d*, Another instrument (not so well known), called an atmometer, invented by the late Professor Leslie of Edinburgh.

The following is the construction of the new instrument:—A pair of sensitive thermometers, having thin cylindrical bulbs, are fixed on a stand in an inverted position (as shown in the annexed woodcut); this position of the thermometer bulbs gives more perfect isolation from the temperature of the resting-place, and surrounding bodies affecting their indications; they are fixed sufficiently apart so as not to affect each other. One of Leslie's thin porous clay bulbs is fitted to the frame, so as to cover and enclose the bulb of one of the thermometers. In the centre of the stand, between the thermometers, a small glass tube reservoir for water is fixed; a thread of cotton-wick, reaching to the bottom of this tube, is conveyed to, and rests upon, the porous bulb, which is thus kept continuously supplied with moisture by capillary attraction.



The bulb of the thermometer thus enclosed is cooled by the evaporation of water from the surface of the porous clay bulb, in the same way, and to the same extent as if it were covered with wet muslin in the ordinary way, and gives, by inspection, all the indications of the wet bulb thermometer; these, with the indications of the dry bulb one, form together Mason's Hygrometer. From the indications of this instrument (as is well known), and by the use of Glaisher's Hygrometrical Tables, the dew point and state of the air as to moisture is easily obtained and determined.

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The glass tube reservoir, in the centre of the stand, is furnished with a graduated scale. Each degree of water in the tube is equal to "one thousandth" part of an inch of depth of water on the evaporating surface or area of the porous ball. These degrees are accurately determined, upon the plan recommended by Leslie, for atmometrical degrees. The scale of degrees reads from (0) zero, at the top downwards —·01, ·02, ·03, and so on; ten of these atmometrical degrees, marked ·01, are equal to one-hundredth part of an inch of depth of water on the evaporating surface or area of the porous ball; twenty of these atmometrical degrees, marked ·02, are equal to one-fiftieth of an inch of depth of water on the area of the evaporating surface; one hundred of these atmometrical degrees, marked ·10, are equal to one-tenth of an inch of depth of water on the area of the evaporating surface, and so on. By successive observations of the level of the water in the reservoir with the scale on it, the rate of evaporation is shown. Should these observations be made and noted daily, then the daily atmometrical degrees added together give weekly, monthly, and yearly the depth of water evaporated, or the amount of the drainage by the atmosphere from wet or humid surfaces.

The evaporation of water goes on in nature unceasingly, from every wet or humid surface, with varying rapidity, according to the dryness and temperature of the air. Leslie, however, proved "that it is always proportioned to the extent of the humid surface," and also "that as much water evaporates when the exhaling surface appears almost dry as when it glistens with abundant moisture." If the area, then, of a wet or humid surface and the atmometrical degrees be known, the quantity of water evaporated in a given time is easily calculated.

Rule.—Multiply the number of square inches of the surface by the atmometrical degrees, and the result is the answer in cubic inches of water, which are easily resolved into measure or weight.

Example.—Suppose the atmometer has indicated ·05 in a day, required the quantity of water evaporated from a pond or marsh of the area of an acre? Answer, 1131 gallons, or

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5 tons. As a rule, it will be near enough for almost any purpose to reckon the rate of one ton per acre for every ten degrees (·01) of the atmometer.

Wind has a great effect in increasing the amount of evaporation. Leslie found from the indications of an atmometer kept in a still place, compared with one exposed, that they became a measure of the rate of the wind. From these things it is evident that atmometrical observations are as interesting and instructive as those of the rain-gauge; indeed, the rainfall of any district is uninstructive, unless the amount of evaporation be at the same time determined and given.

Instructions.

Remove the cap of the reservoir by the bayonet-joint, fill the tube (0) zero on its scale; see that the thread of cotton-wick is wet, and also the porous bulb, then set the instrument in the place fixed upon for observation. Care must be taken not to dirty or grease the porous bulb.

Compensation of the Pendulum for Changes in Temperature and in Atmospheric Buoyancy. By EDWARD SANG, F.R.S.E.*

Before proceeding to describe the group of contrivances indicated in the title of this paper, it is proper for me to say a few words in explanation of my reasons for bringing it forward at the present time. The idea has occupied my mind for many years, and more than a year ago I matured the design which I am about to submit to the Society. My hope of having had the apparatus constructed and in action during the past summer was disappointed, and the paper was delayed until the arrangement should be subjected to actual trial.

Meantime, in my capacity as Secretary of the Society, I received from Mr Macfarlane of Comrie the communication which has been just read. In this Mr Macfarlane anticipates a part of my intended arrangement, and therefore has

* Read Before the Society, 28th February 1870.

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completely established the claim to priority of publication. It is my first duty most distinctly, and also most cheerfully, to admit this claim.

Those members of the Society who have paid attention to this subject will have perceived that Mr Macfarlane's contrivance is an obvious modification of the method for adjusting the beat of a pendulum, for which a medal was awarded to me in 1864. At the same time, they can hardly have failed to notice that his paper contains clear internal evidence of Mr Macfarlane's having been unacquainted with that method. It is therefore my most, and also my agreeable duty, to claim for him entire originality in the idea.

Seeing, then, that delay has allowed part of my arrangement to be anticipated, I have determined to place it at once before the Society, even with the disadvantage of not having the actual apparatus ready for exhibition, lest the rest also may pass away from me.

Something like a quarter of a century ago, Mr Vulliamy of London sent out a steeple-clock to Constantinople; and it so happened that I was requested to superintend its erection in the clock-tower at Tophana which had been built for it.

The custom in the East is to count the hours from sunset till sunset, and therefore it was impossible for Mr Vulliamy's excellent clock to keep true time. I designed a new kind of sun-dial, indicating the Eastern hours by means of an image of the sun made upon the concave surface of a sphere, and which could easily give the time to within a fraction of a minute. This dial was erected at the foot of the clock-tower, and serves to set the clock from day to day.

In order to avoid this continual meddling with the clock, I set to work to contrive some means of changing its daily rate. The only expedient which could be used with such a heavy pendulum as that of the clock was to change its effective length, by causing the suspending spring to pass through a slit, and to give an up-and-down motion to that slit. This slit was to be made in a lever, the far end of which rested on the periphery of a disc, cut of such a shape

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as to correspond with the varying length of the day throughout the year; and this disc was to turn once in the equinoctial year. The train was calculated, the wheels cut: the equation, adjusted to the mean elliptic motion of the earth and to the latitude of the place, was carefully computed for each day of the year; the brackets for securing the apparatus to the clock-frame were ready; but, on ascending to take the first steps for affixing the new parts, I found the clock neatly enclosed in a glass case, which effectually prevented any operations. As this glass case had been placed by *superior authority*, my case was hopeless, and the equation apparatus has not been applied.

This idea is carried out, though for another purpose, in my pendulum suspension for adjusting the beat; the extension of it to the correction for changes of temperature is sufficiently obvious. My object is to modify it, so as to combine the corrections for changes in temperature and in atmospheric density.

The highly satisfactory performance of this slit-adjustment in the case of the mean-time clock at the Royal Observatory of Edinburgh, encourages me to expect of it sufficient delicacy and precision to reach even to the small inequalities due to fluctuations of the atmosphere. When the old suspending piece was removed, and the new one with the moveable slit substituted, we were agreeably surprised to find the arc of oscillation considerably augmented.

Encouraged by this success, I propose, by help of the slit arrangement, to accomplish the following objects:—

1. The accurate regulation of the clock's mean rate.
2. The setting of the clock forward or backward by any prescribed small fraction of a second.
3. The compensation for changes in temperature and the adjustment of that compensation.
4. The compensation for changes in atmospheric pressure and also its adjustment.
5. The avoiding of any interference with or stoppage of the pendulum in any or all of these operations.

The pendulum is supported by a strong brass plate, firmly bolted to the wall or stone pillar prepared for the clock. On

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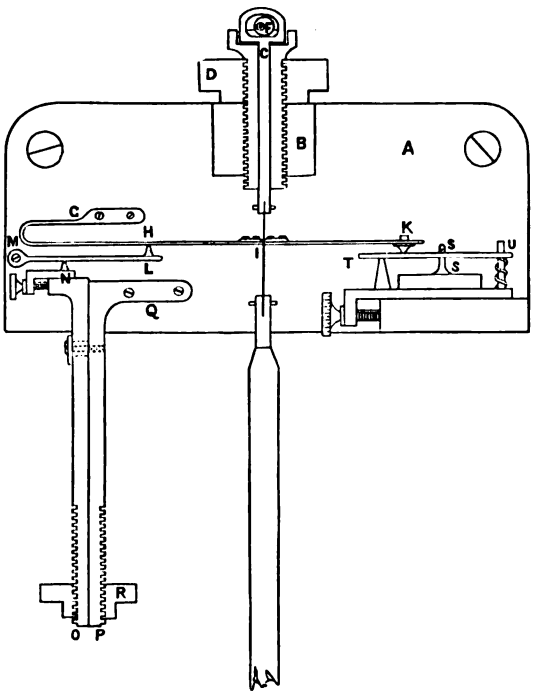
the upper part of this plate A, there is cast a projection B, in which a cylindric hole is carefully worked, the upper part of the projection being turned true to the axis of the cylinder.



A strong brass screw, with square threads, is fitted to a cylindric hole, so that it may slide steadily; the screw is prevented from turning by a key secured by two small nails in front; these are not seen in the drawing.

A large brass nut, D, is carefully fitted to the screw; this nut bears upon the flat upper face of the projection B; and by turning the nut D round, the screw is raised or lowered.

The thread of this screw, and of its nut, are finished carefully as if for linear graduation, and the pitch is arranged so that one turn of the nut D makes a change of fifty seconds in the clock's daily rate. The enlarged part of the nut has its circumference divided by lines into 500 equal parts, and

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each of these parts is subdivided by means of a vernier into ten, so that the hundredth part of a second in the daily rate can be easily estimated.

The thick screw has a hole pierced along its whole length, and carefully finished to be truly cylindric; into this hole a steel carrier C is fitted with a groove and key to prevent its turning; to the lower end of this carrier, the upper end of the pendulum spring is securely fastened. This steel carrier C is expanded at its upper end into a bridge, through the span of which a steel axis F has room to pass.

This axis F rests in two bushes made in the upper part of the screw, which is enlarged for the purpose. In the middle of the length of the axis F a projection is made, not cylindric, but composed of parts of three cylindric surfaces connected by sloping parts. The radii of these three partial cylinders are equidifferent, and the difference is computed so as to cause a change of one second per fifty minutes in the clock's rate. The bridge of the carrier C rests upon these projections from the axis F, which thus virtually supports the pendulum.

In order to turn the axis F into the desired position, a continuation is loosely jointed to it, which continuation is brought forward to the dial plate, where it carries an index. At distances of 120° on the circle of that index the letters M, G, L (or others equivalent) are placed. When the index is turned to M (mean) the pendulum is of its mean length, and the clock should be going to mean or true time. When the index is turned to G (gaining) the pendulum is shortened and the clock should be gaining at a known rate, the convenient change being one second in fifty minutes. And, when the index is at L (losing) the pendulum is lengthened.

Thus if the clock be fast of true time by say $0^{s}{\cdot}47$, we turn the index to L and keep it there for $23^{m}\ 30^{s}$ in order to retard the clock to true time.

The partial cylindric surfaces extend a good way on each side of 120°, so that it is not necessary that we be very careful in setting the index.

To the plate A, a steel spring GHIK is firmly secured at the end G. The part HIK is straight and stiff, while the

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more flexible part from G to H is so adjusted as to make both ends of HIK to pass downwards against resistances provided for them. At I, the middle of HK, there is a slit through which the pendulum spring passes, and this slit is furnished with two hardened adjusting pieces which are regulated to the thickness of the spring and to its position when the pendulum is at rest.

In this way HK must be regarded as a straight bar resting on props at H and K, and being prevented from motion endways by the longitudinal resistance of the spring GH.

The part H rests upon a stud L fixed on the lever ML. The under side of this lever is dressed straight, and presses against a knob N, fixed on the upper end of a long steel piece NO; the lower end of which we may, for the moment, suppose to be attached to the lower end P of a long brass piece PQ; the upper end Q of that brass piece being secured to the plate A.

The consequence of this arrangement is, that when, by an increase of temperature, the pendulum rod becomes lengthened, the part QP expands downwards, the steel piece ON upwards; so that, since brass expands more than steel, the point N, and consequently the point I, is lowered, so as to shorten the effective length of the pendulum.

The adjustment of this compensation is shown as effected in two ways. The one of these is to give a horizontal motion to the knob N by means of a screw acting on the upper part of the steel piece NO. By drawing N nearer to the fulcrum M, the action of the compensating parts is augmented. The head of the screw is graduated to hundredth parts of a turn; and the sliding piece is marked in whole turns, so as to indicate definitely the position of the knob N. This, which is the coarser adjustment of the compensation, may be omitted after the first trials, and the position of the knob may be permanent. The second and more delicate adjustment is obtained by altering the effective lengths of the pieces NO and PQ. Instead of securing them permanently at their lower ends, I make each of them the half of a screw on which a nut R works. These pieces are carefully slid and screwed on the screwing lathe, and the screws finished

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by grinding. By turning this nut round, the effective lengths of the two expanding pieces are changed; and by having the periphery of the nut graduated we can adjust these lengths with the utmost nicety, and that without making any perceptible change even on the clock's rate at the time of the adjustment.

The oscillation of the pendulum is caused by its gravitation, and every change in the intensity of that gravitation must be accompanied by a change in the clock's rate. Now the effective gravitation of the leaden pendulum bob is its intrinsic weight, less the weight of the air which is displaced by it; and the weight of a given volume of air changes with the temperature and with the pressure. That part of this influence which is due to change of temperature will be disposed of by the already described arrangements; and we have now to consider the correction which has to be applied for changes in the barometric pressure.

For this I place the receptacle of an aneroid barometer upon a strong sole-piece fitted to slide horizontally upon the principal plate A. The stud and lifting pin S of this receptacle rests upon a strong straight lever TV, which again is supported at the end T by a strong fulcrum, at the other end U by a spiral spring. The upper surface of this lever is dressed flat, and sustains the stud K on the end of the spring GHIK.

When the barometric pressure is augmented, the spring at V is compressed, the stud K is lowered, and consequently the working length of the pendulum is shortened, so as to compensate for the diminished gravitation of the leaden bob. The adjustment of this compensation is effected by sliding the whole apparatus R, T, U horizontally by means of a graduated leading screw. Care is taken to make the upper face of the lever TV horizontal for the mean state of the barometer, in order that the operation of adjustment may derange as little as possible the clock's rate at the time.

In this arrangement, the pendulum is made securely of one piece, without any internal movements or adjustments, thus giving great steadiness to the performance. The pendulum rod should be of deal or of glass on account of the

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small rate of expansion of these substances; the load should be of lead, and its form should be that of a cylinder, or of some other solid of revolution, in order that inaccuracy may not be introduced by any twisting of the rod or of the spring. Lead is the heaviest of all the metals available for this purpose, and, in consequence, the influence of changes of atmospheric density is the least when it is used.

In order to verify the compensations and to determine the value of the graduations, the pendulum with its clock-work must be inclosed in an iron box with an air-tight cover of glass. Means must be provided for keeping this box steadily at a desired temperature for a long while, and also of varying the pressure within it; a thermometer and a barometer must also be inclosed.

By comparing the clock with an astronomical timekeeper, under various circumstances and with various readings of the different adjustments, a set of equations of condition will be obtained, by means of which we can compute the true zeroes of the adjustment, and the effective values of their divisions.

After this it is in the power of the astronomer into whose hands the pendulum may come, to verify and to adjust all the compensations for himself, thus freeing him from all dependence on the accuracy of the original workmanship and adjustment.

Suggestion of a Universal Alphabet and Mode of Writing and Printing for the Blind. By EDWARD SANG, F.R.S.E.*

It is now thirty-eight years since this Society offered a handsome premium for the best alphabet and mode of printing for the blind. The committee appointed to consider the various schemes then proposed, gave in an elaborate report, of date June 1837, which report is inserted in the first volume of the Society's Transactions.

The opinions expressed in that paper, most ably drawn up by the committee's convener, the late Mr William Fraser,

* Read before the Society 14th March 1870.

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bring out the whole of the difficulties of the question which the Society had set itself to solve.

In the first place, we must have characters easily distinguished by the touch; and we are thus induced to seek for the simplest set of marks for an arbitrary alphabet.

But, in the second place, by the adoption of a strange alphabet we effectually debar the blind from literary correspondence with the great mass of the seeing; wherefore it is desirable to have some alphabet resembling those in common use.

We have thus two desiderata, seemingly antagonistic to each other; and the difficulty has been to reconcile them.

The committee, taking a strong view of the great importance of keeping the blind in easy communication with the rest of the population, gave the preference to a modification of the Roman characters. The experience, however, of the working of this system has not been such as to throw decisively out of view the relative advantages of other systems, and hence, even yet, the discussion is continued between rival partisans, to the great loss and inconvenience of our blind brethren. I have in my hand an excellent article from the "Times" newspaper of January 3, in which the great advantages of Braille's system of dots are well stated; and also a letter from our able coadjutor the Rev. Mr Taylor of Worcester, published in the "York Herald" of March 5, advocating the banishment of every alphabet but the Roman.

The great want is an alphabet easily deciphered by touch, and known to those who see. That which it was impossible for any one to have contrived has come to us in the course of social progress. The necessities of the telegraphic engineer have presented us with an unexpected solution of the difficulty.

Morse's alphabet for the telegraph is obtained by combining long and short strokes, all extended in one line, with long and short spaces. Scarcely any scheme could be contrived affording greater facilities for discrimination by the touch. There is no need for feeling to the one side or to the other in order to judge of shape; we may substitute dots

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for the short lines, and shorter lines for the long ones, for the sake of condensation, without thereby changing the characters; and therefore this system may compete successfully with all other artificial systems.

But to present the blind with even the very best possible alphabet, would be to offer them a useless gift: their object is not to be able to read for the mere sake of reading, but to be able to hold intercourse with their fellow-men. In their asylums and segregate workshops they are already too much withdrawn from general society; their reading, in order to be useful, must bring them into communication with their seeing friends. So we can only judge of the comparative advantages of the telegraphic system to the blind by estimating the number of seeing persons who are likely to become acquainted with it.

Now, in the first place, telegraphic correspondence is rapidly becoming so general, that at every small hamlet throughout the country, clerks able to write and read the alphabet will be found. Those connected officially with the telegraph stations will outnumber many times the whole aggregate of the blind. With all of these the blind will be in immediate communication.

But more, now that the telegraphic service has been taken in hand by the Government, and that messages are multiplied, it will come to pass that in establishments to which many telegrams are sent, there will be clerks able to read the message from off the machine paper; that the actual papers will be sent to them at a lower charge than the decipherment, to the ease of the office, and to the greater privacy of the message. In this way, besides the professional telegraph-office clerks, there will soon be a multitude of outsiders; and the telegraph alphabet will come to be taught in all our common schools.

In order to enable the blind to write according to this system, we have only to prepare a sheet of lateen brass, thin zinc, or even cardboard with parallel slits cut in it. With a common pencil the blind person can then make the short and long strokes, and so complete his letter, which will be intelligible to any seeing person acquainted with the system.

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If he wish to write to a blind friend, he must be provided with a plate or board slightly grooved to correspond with the slits in his sheet of zinc. By placing the paper over this board, and then the zinc above the paper, and by using a blunt steel style instead of a pencil, he can indent the paper, so as to produce the characters in relief on the opposite side. If the writer have begun at the top of the page, the reader must, when the paper is inverted, begin at the foot; so that it will be proper to cut off a small piece from the initial corner as a mark.

There is no system which requires an assortment of fewer types for printing. Lines on *en* and *em* bodies, *en* spaces, *em* spaces, and *two-em* spaces, in all five varieties, complete the fount. The lines would need to be separated by leads, or they may be set in grooves according to the plan proposed by Mr Alston.

Impressions could then be taken in ink for the seeing, or embossed in soft paper for the blind, who would thus be able to read and to send circulars or announcements.

The types are to be found ready of all sizes in the type-foundries, and a few trials will be sufficient to tell the smallest size that can be used with advantage, as well as the thickness of lead necessary to secure distinctness between the lines. On account of the great facility of the type setting, it may be preferred to writing, even for a single letter, the more so as it would enable the composer to revise and correct his composition. Of course, a code of simple rules would need to be compiled to regulate the ending of one and the beginning of the next line.

A New Planisphere, for showing the Altitude and Azimuth of the Sun or a Star. By JOHN LOVE, Royal Bank, Greenock.* (Plate III.)

THE CONSTRUCTION OF THE PLANISPHERE.

The object of this contrivance is to illustrate mechanically the observer's relations to the path of a celestial body, and

* Read before the Society 25th April 1870, and awarded the Society's Silver Medal and Plate, value Three Sovereigns.

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more especially to the sun's path ; and the means employed for this purpose consist simply of two stereographic projections of the sphere, one of which is to lie symmetrically on the surface of the other, and to revolve over it on their common centre. Both projections are drawn on the plane of the meridian: the one on an opaque disc, being a representation of the sphere, with reference to the lines of its *motion*, and the divisions of its *time;* and the other on a transparent disc, being a representation of the sphere with reference to its lines of *altitude* and *bearing*. The arrangement shows the systems of circles which respectively pertain to those two aspects of the sphere; and it is the intersections of the lines of the two systems, read through the transparency, which are to tell the intended story.

I. *The Opaque Disc.*

This disc is designed to represent the celestial sphere as projected on the plane of the meridian, but the circles delineated upon it have reference more exclusively to the revolution of the sphere round its axis, and to those divisions by which the time of that revolution is measured into hours. With the aid of the plate, the following description of this disc will be readily followed :—

1. The circle which encloses the figure is the observer's *meridian.*

2. The straight line ending in the north and south poles is the *axis* of the celestial sphere.

3. The straight line which cuts the axis at right angles represents the *equinoctial*, or equator of the heavens.

4. The lines to the north and south of the equinoctial are the *parallels of declination.* Along with the equinoctial they represent the circles in which the fixed stars revolve round the celestial axis. Up to the tropics they show that portion of the heavens through which the sun travels in his annual course.

5. The lines passing through both poles are the *hour circles*, the observer's meridian being one. They are set down on the disc at intervals of 15°, and mark, therefore, on the equinoctial and its parallels, periods of one hour from

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each to each. Fractions of time less than an hour may be estimated by the eye between the hour lines. On the left hand is the line of noon; on the right hand the line of midnight, the morning hours being written along the equinoctial on the upper side, the evening hours along the same line on the lower side. The straight line running from pole to pole, which has been already referred to as the axis, represents also the observer's six o'clock hour circle. The angle at the pole which the hour circle passing through a celestial object makes with the meridian, is the hour angle of that object's position.

6. This disc is primarily intended to represent the *celestial sphere*, but it serves equally well to represent the *earth;* only it is obvious that with reference to the sphere, the observer's position is in the centre, while, with reference to the earth, his position is on the meridian.

7. The numbers round the meridian of this disc show the distances from the equator in degrees; if from the equator of the heavens, they are degrees of *declination;* if from the equator of the earth, they are degrees of *latitude.*

II. *The Transparent Disc.*

This disc also represents the celestial sphere as projected on the plane of the meridian; but the lines which are exhibited here are the horizon, and the system of circles of which it is the equator. As in the other case, the reader, with the assistance of the annexed plate, will readily follow a description of this disc.

1. The circle enclosing the figure is again the observer's *meridian.*

2. The straight line ending in the north and south points is the *rational horizon.*

3. The straight line at right angles to the last mentioned is the *axis* of the horizon. Its terminal points, namely, the zenith and nadir, are the *poles* of the horizon.

4. The lines above and below the horizon are the *parallels of altitude,* which measure the space between the horizon and its poles. The degrees of altitude are indicated along

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the inner side of the meridian. The dotted parallel at 18° below the horizon shows the *limit of twilight.*

5. The lines passing through the zenith and nadir are the *vertical circles*, the observer's meridian being one. They are set down on the disc at distances of $11\frac{1}{4}°$ from one another, and mark, therefore, on the horizon and its parallels, intervals of one "point" from each to each, the angle at the zenith corresponding to a point of the compass being $11\frac{1}{4}°$. Smaller angles may be determined by the eye between the represented lines. The points of the horizon between the north and south points, going round by the east point, are written on the disc along the upper side of the line, those going round by the west point being written along the lower side. The straight line running from the zenith to the nadir, which has been already noticed as the axis of the horizon, represents also the *prime vertical* of the observer's sky. The angles which the vertical circle passing through a celestial object makes with other vertical circles are clearly defined; its inclination to the meridian is the *azimuth* of the object, its inclination to the prime vertical is the object's *amplitude.*

6. The lines of this disc, like those of the other, may be referred to the *earth* as well as to the celestial sphere. The point which, as to the sphere, represents the zenith, under which lie all the heavens, as to the terrestrial globe, represents the position of the observer himself, under whom lies all the earth. The plane of the rational horizon divides the earth as well as the sphere into two equal parts. With reference to the sphere, the parallels of altitude will readily show the distance from the zenith to any object in the heavens; with reference to the earth, they will show the distance in degrees from the observer to the place where that object at the moment is vertical. And so with the vertical circles: as applied to the sphere, they meet in the zenith, and connect that point with every possible position of a celestial object; as applied to the earth, they meet at the observer's feet, and connect his position with every possible place in the world. What is called "great circle sailing" involves, in every instance, an attempt to sail along one of the vertical circles of the earth.

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III. *The Two Discs, combined to form a Planisphere.*

When the discs are combined by placing the transparent one symmetrically on the surface of the opaque one, the two figures unite. Their points of view coincide as a common centre, and the whole projection of the one enters harmoniously into the whole projection of the other, the meridian being the common plane and the common boundary. (*See Diagram.*)

There are now four straight lines passing through the centre. These represent the equinoctial, the six o'clock hour circle, the horizon, and the prime vertical, all being great circles at right angles to the meridian, and all cutting each other in the centre of the figure, which is the *pole* of the meridian. The other circles, small and great, are bent into varying curves according to the requirements of the stereographic projection.

The two discs now form a *planisphere*, which may be employed, with reference to any part of the earth's surface, to show the relations of an observer's position to the positions of the celestial bodies—that half of the planisphere which is on the zenith side of the horizon obviously representing the *visible* sky, while that half which is on the nadir side represents the *invisible* sky.

The meridian is marked for the degrees of declination or terrestrial latitude all round; but when the planisphere is in use, it will be understood that the zenith point must always be placed on the *noon* side of the meridian, and ought always to appear at the top of the figure, the nadir appearing at the bottom.

If the reader will now imagine the united figure to be the sphere which it represents, and himself to be situated in the centre thereof, with his face towards the north point of the horizon, the south point being straight behind him, the east point will be on his right hand, and the west point on his left hand; while the great line of the meridian will stretch above him, affording at one point, namely, in the zenith, a meeting-place for all the vertical circles; and at another point, namely, in the elevated pole, a meeting-place

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for all the hour circles,—the distance, in degrees, between those two points being the complement of the latitude.

The Use of the Planisphere.

The zenith is to be used as a pointer to *set* the horizon to the desired latitude; and this will be done by turning round the transparent disc till the zenith point rests precisely upon the given degree of latitude as marked on the noon side of the opaque disc below it. The nadir will then point to the same degree of latitude on the other side of the meridian, and the north and south points will each stand opposite the complementary latitude. As the horizon and equinoctial also must cross each other exactly in the centre of the figure, there are altogether five check points for securing accuracy in the adjustment of the apparatus for inspection.

I. *At the Equator.*

Set the pointer to the equator, latitude 0°, and turn round the discs till the zenith appears at the top of the figure. The reader will then observe as follows:—

1. The plane of the horizon coincides with that of the six o'clock hour circle, and divides the sphere along its axis—the celestial poles being both on the horizon, the north pole in the north point, and the south pole in the south point, and the equinoctial and all the parallels of declination being cut into two equal parts. It follows, as may be seen by tracing the lines of the parallels of declination, that in the case of every celestial body, one-half of its course is run below the horizon, and the other half above it. Rising or setting all the year round, the stars cross the horizon at intervals of twelve hours *sidereal* time, the sun at intervals of twelve hours *solar* time. For the same reason the sun's depression at midnight is always equal to his altitude on the same day at noon.

2. The prime vertical coincides with the equinoctial. Hence, at the equator, when the sun is on the equinoctial he is also on the prime vertical. His amplitude at rising and setting is 0°, because he rises in the east point, and sets

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in the west point; and his azimuth all day is 90°, because the equinoctial which he is traversing passes through the zenith. Passing thus also along one and the same vertical circle, every degree of advance in his diurnal course makes a degree in altitude or depression through all the hours of day and night. Stars on the equinoctial have never, at the equator, any other bearing than due east or west, and have an unvarying velocity in altitude of 15° per sidereal hour.

3. When the sun is in declination north or south, there are constant variations in his bearing and in the altitude to which he ascends at noon. His meridian altitude varies twice a year from 90° to 66½°. His amplitude varies precisely with his declination; thus, in declination 10°, his amplitude is 10°. The extent of his changes in azimuth varies precisely with his meridian altitude; thus in declination 20° north his meridian altitude is 70°, and his azimuth between sunrise and noon varies 70°. Here, except at the equinoxes, he never touches the prime vertical; in north declination he is all day north of east and west; in south declination he is all day south of those points. He never, by day or night, crosses any of the vertical circles which lie between his point of rising and the east point, or between his point of setting and the west point—a remark which, at the equator, applies also to all stars in north or south declination, up to the poles.

4. At all declinations the sun's bearing changes very slowly for some time after sunrise; but the changes occur earlier and more equably throughout the day as the declination increases. When he is in declination 4°, for example, his azimuth alters only one point between six o'clock and eleven, and must then, in the remaining hour till noon, alter farther more than 6½ points; whereas, in declination 18°, his azimuth between six o'clock and eleven alters three points, and has then less than 3½ points to run through before noon. The rate of his progress in altitude, again, will be observed to slacken towards noon as his distance from the equinoctial increases. Compare, at different declinations, the altitude made in the two hours before ten o'clock with that made in the two hours after ten.

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II. *Between the Tropics.*

Set the pointer to any latitude between the tropics, north or south, and adjust the apparatus in every instance so that the zenith will appear at the top. The following particulars will then be observed:—

1. The plane of the horizon now cuts the celestial sphere at an angle to its axis, and to the six o'clock hour circle, which angle is the equivalent of the latitude. For a number of degrees equal to the latitude, one pole is above the horizon and the other below it. Stars, whose distance from the elevated pole does not exceed the latitude, never set, and are for that reason called "circumpolar" stars; those on the corresponding parallels of declination around the depressed pole never rise. All the other parallels are cut by the horizon, and cut into unequal parts. But, in intertropical latitudes, where the inclination of the horizon never exceeds about $23\frac{1}{2}°$, the parallels of declination which are traversed by the *sun* are divided by the horizon into two parts, the inequality of which is nowhere extreme. In latitude 18°, for example, the horizon and the *half-past five* o'clock line cut each other in the twenty-second parallel. By adjusting the planisphere to any of those latitudes, a view of the semidiurnal and seminocturnal arcs proper to each latitude will be at once obtained. It will be observed, at the same time, that the portions of those arcs which are intercepted between the six o'clock hour circle and the horizon, form a diagram roughly resembling a *sandglass*, which exhibits, for the given latitude, the extent beyond or within twelve hours of the variations in the length of day and night throughout the year.

2. The prime vertical is now inclined to the equinoctial at an angle which, applied to the earth, is the latitude of the observer's place. It cuts above the horizon the parallels of declination which lie between the zenith and the equinoctial, and below the horizon it cuts an equal number of those parallels beyond the equinoctial. Only those stars, accordingly, which are on the equinoctial and on the intersected parallels lying on the zenith side of that line, have,

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to the observer, any due easterly or westerly bearing; and the time during which the azimuth of the *sun*, also, rises or falls to 90°, is limited to the periods in which, going and returning, he traverses the same space. Set the pointer to latitude 10° north, and it will be remarked that, when the sun is approaching the observer from the south, he has no easterly bearing—his azimuth is never down to 90°—till he reaches the equinoctial, and then he rises in the east point and sets in the west point, exactly at six o'clock. From that time till he reaches declination 10°, he crosses the prime vertical every day, but every day at an increased altitude and a later hour. Thus, in declination 4°, it is half-past seven before he bears due east; in declination 8°, it is about half-past nine; in declination 10°—corresponding to the latitude—his easterly bearing ceases, since his path then does not *cut* the prime vertical, but simply coincides with it in the zenith at noon. From that point to the tropic of Cancer, and back again, the sun is always north of the prime vertical, and his azimuth less than 90°. Set the pointer, now, to latitude 20° north, and it will be seen that the sun crosses the prime vertical, on the equinoctial, at six; in declination 8°, at half-past seven; in declination 16°, about half-past nine. In declination 20°—corresponding to the latitude—he merely touches the prime vertical as he crosses the meridian, and keeps to the north of it from thence till he returns to the same parallel on his way south. It is obvious, that, in every instance, when the sun crosses the prime vertical, however high in the day, he must, in the interval, till noon, run through the whole quadrant of bearings between that vertical circle and the meridian.

3. Turn again to the horizon, and observe the manner in which it is cut by the parallels of declination, and by the hour circles. (1.) The points in which it is cut by the parallels of declination determine the *amplitude* of the object. The arcs of the horizon intercepted between those parallels and the east point, as we saw, coincided, at the equator, with the similarly intercepted arcs of the six o'clock circle; and, accordingly, the amplitude and the declination were then equal. The horizon, however, is now inclined to the six

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o'clock circle; but, in these latitudes, the inclination is so comparatively small, that the corresponding intercepted arcs are not yet greatly dissimilar, and, accordingly, the amplitude does not much exceed the declination. At either tropic—to take the strongest example—when the sun is in the zenith at noon, that is, in declination 23½°, his rising and setting amplitude is only 25¾°. (2.) Contrast now the equal parts, of 15° to an hour, into which the *equinoctial* and parallels of declination are cut by the hour circles, with the unequal parts into which the *horizon* is cut by the same circles. In the example already cited—latitude 18° north—the six o'clock and half-past five o'clock lines intercept, on the horizon, an arc fully three times greater than that which they intercept on the equinoctial. The relation, indeed, of these two sets of arcs was once the most familiar of mathematical ideas, because it regulated the construction of the chief time-keeper, the dial. The arcs of the equinoctial and its parallels, as measured by the hour circles, show the *time* of sunrise, and the duration of light; the arcs of the horizon and its parallels, as measured by the vertical circles, show the *direction* of sunrise and the length and course of the shadow.

4. As may be seen in the planisphere, celestial bodies whose polar distances are less than that of the observer, describe curves through the visible heavens which carry them *twice* through some of the vertical circles which they cross, on the *same* side of the meridian; circumpolar stars pass twice through *all* the vertical circles which they cross. With reference to the sun, set the pointer to latitude 20° north, and it will be observed that when he is in declination 22° north, he rises a little before half-past five, 1° north of E.N.E.; comes gradually southward for a point and a quarter, being south of E. by N., from sometime before nine o'clock till after eleven; then *returns* through the same bearings northwards, and is shortly due north, on the meridian, 2° from the zenith. In the same latitude, when the sun is on the tropic of Cancer, he rises, a few minutes before half-past five, about a quarter of a point north of E.N.E.; comes southward till, for sometime before and after ten o'clock,

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his path runs along at a very small distance from the E. by N. vertical, and then bends northwards to the meridian, *repeating* all the azimuths of the morning. In the days when dialling was a branch of every student's education, this phenomenon was well known as "the retrogradation of the shadow," and had sometimes a controversial interest imparted to it in discussions regarding the dial of Ahaz, twice mentioned in Holy Writ. The latitude of Jerusalem is, indeed, far north of the region where an arc of the horizon can, at any season, be twice traversed by the *sun;* but, without touching the extraordinary and sacred character of that event, we know that by means of an *inclining* dial, duly adjusted, the sun's shadow may be made to double upon itself, anywhere, every summer day, as it does between the tropics.

5. With reference to the sun's altitude in this part of the earth, observe—(1.) Every place within the tropics has two vertical transits of the sun every year; but the time occupied in the ascent to the zenith is greater, and the rate of progress in altitude less, as the latitude increases. In proof of this, set the pointer successively to several of these latitudes, and observe the increasing *obliquity* of the sun's path across the vertical circles as we recede from the equator. (2.) Excepting at the equator, the intervals between the vertical transits are *unequal*. Thus, in latitude 10° north, the extreme meridian zenith distance northwards is $13\frac{1}{2}°$, the extreme meridian distance southwards $33\frac{1}{2}°$. At the equator, and, in an inferior sense, everywhere else between the tropics, there are thus two summers and two winters in the year. Near the tropics, indeed, the result is rather one winter and an intense double summer. In latitude 18° south, for example, the sun's meridian zenith distance, when he is at the tropic of Cancer, is $41\frac{1}{2}°$—in other words, his meridian altitude is then only $1\frac{1}{2}°$ greater than it is at the same moment on the Arctic circle. When he returns southward, however, and reaches declination $12\frac{1}{2}°$, he is within $5\frac{1}{2}°$ from the zenith at noon; and, during the whole time of his passage to the tropic of Capricorn, and back again to declination $12\frac{1}{2}°$, his meridian zenith distance does not *exceed* that amount. In

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other words, to an observer in latitude 18°, north or south, the sun, during *twenty-two degrees* of his annual course, is never farther from the zenith at noon than $5\frac{1}{2}$°, and that at the period when his motion in declination is slowest, and the length of the day is greatest. The accumulation of heat under such circumstances must be extreme, and the contrast to the winter temperature very remarkable. (3.) An observer under the vertical sun has, for the moment, the whole *illuminated half* of the world above his horizon, the whole unillumined half beneath it. The experience of an observer at antipodes to him is, at that instant, of course, exactly the reverse. The one is in the axis of the earth's light, the other in the axis of its shadow. As the inhabitants along the line of the equator are each other's antipodes, it follows that, when the sun is on the equinoctial, an observer at the equator will pass, on the same day, from the maximum of light at noon to the maximum of obscurity at midnight. The torrid zone of the earth, which is the exclusive domain of the vertical sun, is thus the scene not only of the world's loftiest days, but also of its profoundest nights; and, if it be admissible to suppose that the *darkness* around the observer increases gradually, by however slight degrees, with the extent of the shadow, this *may*, in part, explain the reason why those skies, by night, are so renowned for their brilliancy and depth.

III. *From the Tropics to the Poles.*

What remains may be more briefly disposed of.

1. *The Temperate Zone.*—Set the pointer to latitude 56° north—*see Diagram.* The horizon is now more inclined to the *six o'clock hour circle*, so that the two lines intercept between them larger arcs of the parallels of declination, and, accordingly, the inequality of the semidiurnal and seminocturnal arcs has increased, and the diagram of their variations become wider. When the sun is at the summer solstice, he rises at twenty minutes past three; when he is at the winter solstice, he rises at twenty minutes to nine. With the implied increase in the elevation of the pole, the

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number of circumpolar stars has increased. The horizon is now less inclined to the *equinoctial* and to the parallels of declination, cutting those parallels which it intersects into more unequal parts; so that the *amplitude* increases with the declination in a more rapid ratio. In this latitude, at the solstices, the amplitude is 45° 24′. The *prime vertical* is more inclined to the equinoctial, and, accordingly, at the equinoxes, the angle at which the sun's path bends away from the observer is increased—increasing exactly with the latitude. The prime vertical now cuts *all* the intertropical parallels of declination, so that it is crossed every day in the year by the sun, in winter below the horizon, in summer above it; but, with the altered inclination of this vertical circle, those arcs of parallels which are intercepted between it and the six o'clock hour circle have become smaller—easterly bearing occurring earlier in the day. The altitude at noon is diminished with the increased distance of the observer from the equator, and the rate of the progress in altitude is diminished with the increased obliquity of the sun's path. In latitude 56° north, when the sun is in declination 10° north, he rises at one minute to five, with an amplitude of 18° 6′, and, consequently, an azimuth of 71° 54′; at twenty-eight minutes past six, his bearing is due east, in crossing the prime vertical; at ten minutes past eight, he bears E.S.E.; at twenty-one minutes to ten, S.E.; at seven minutes to eleven, S.S.E.; at twelve, he is on the meridian, bearing due south.

2. *The Arctic Circle.*—Set the pointer to the intersection of the Arctic circle with the meridian—latitude about 66½° north. The horizon now coincides with the ecliptic—the tropic of Capricorn being in the south point, and the tropic of Cancer in the north point. When the sun is at the tropic of Cancer, the semidiurnal arc is 180°, the seminocturnal arc, 0°; when he is at the tropic of Capricorn the latter is 180°, and the former 0°; in both cases the amplitude is 90°—the azimuth at sunrise in summer being 0°, in winter 180°. At the summer solstice the sun is on the horizon, in the north point, at midnight, and, to an observer in this latitude, he must by noon cross all the vertical circles on the eastern

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side of the meridian, and between noon and midnight again all those on the western side. At the winter solstice he is on the horizon, in the south point, for a moment at noon, and to the same observer he has no other bearing. As the declination decreases, the amplitude decreases; the arcs of the horizon, accordingly, traversed between sunrise and noon, and between noon and sunset, in summer decreasing, in winter increasing, till the sun is on the equinoctial, when he rises and sets here, as elsewhere, at six o'clock, with an amplitude of 0°. When the pointer is at declination 66½° north, it will be observed that the vertical circles and parellels of altitude become available as the circles of *celestial* latitude and longitude.

3. *The Poles.*—When the pointer is set first to the north pole, and then to the south pole, it is seen that in both cases the horizon coincides with the equinoctial, and the axis of the horizon with the axis of the celestial sphere. The declinations of the sun and stars are their altitudes, their azimuths are their hour angles. The whole zone of the sun's path is in view—at the north pole, from the equinoctial to the tropic of Cancer and back again; at the south pole, from the equinoctial to the tropic of Capricorn and back again. In each case all the celestial meridians meet in the observer's zenith, which is the pole of the heavens; and all the terrestrial meridians meet in the point where he stands, which is the pole of the earth. The supposed occupant of the pole, therefore, may choose any line in the heavens, and call it his meridian, one of its intersections with the horizon being his north point, and the other his south point. His day is all noon, and his night all midnight; or rather, we may say, his year has but one day, of which the noon-point is the visible solstice, and but one night, of which the midnight point is the solstice invisible. There is here no daily rising and falling of the sun, in the ordinary sense; the only motion from hour to hour, and from week to week, being a motion round and round the sky, with a scarcely perceptible spiral advance continually upwards to altitude 23½°, and then continually downwards to the horizon, and on to a depression of 23½° below the horizon.

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Deducting 18° for twilight, there are thus, at the deepest season, never more than 5½° of full darkness at the unlighted pole.

4. *The Equinoxes.*—One of the most striking of the familiar phenomena of nature is the universal equality of day and night at the equinoxes, with the simultaneous easterly bearing of the sun at rising, and his simultaneous westerly bearing at setting, to all observers on any one meridian. The planisphere clearly illustrates the reason why. The equinoctial, the six o'clock hour circle, and the horizon and prime vertical of every observer, are great circles which cut the meridian at right angles, and which, accordingly, *all meet* in the *pole of the meridian,* which, as it has been explained, is in the centre of the figure. When the sun is in the pole of the meridian, therefore, he is, at that moment, for all observers at once, on the equinoctial, on the six o'clock hour circle, on the prime vertical, and *on the horizon.* To every observer along the whole line of 180° of the meridian, from one pole of the earth to the other, the sun, when he is on the equinoctial, thus appears at six in the *east point;* and, at the same moment, to all their antipodes, he appears in the *west point.* This is mathematically true of that meridian which is at right angles to the ecliptic; and roughly true of all other meridians.

IV. Conclusion.

1. *To find the Altitude and Azimuth of the Sun or a Star.*—Having set the pointer to the given latitude, find the declination of the celestial object, and its hour angle in apparent time. These elements determine its position on the opaque disc, and, by inspection, also on the transparent disc. Or, the declination and altitude being given, the hour angle and azimuth may be found.

2. *Definitions of Arcs and Angles.*—The pointer being set to any latitude, observe the definitions which the planisphere gives of such angles and arcs as those of the latitude, co-latitude, declination, polar distance, altitude, zenith distance, hour angles, azimuths, amplitudes, &c., and the facility

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with which the construction of diagrams involving such arcs and angles may be traced upon it by the youngest student.

3. *In Dialling.*—In the accompanying diagram, the angle of the *stile* of a horizontal dial, for latitude 56°, north or south, is seen in the inclination of the axis of the heavens to the horizon; and the angular divisions of such a dial are shown in the arcs of the horizon intercepted between the several hour circles and the meridian. The angle of the stile of a vertical north or south dial, for the same latitude, is seen in the inclination of the axis of the heavens to the axis of the horizon.

4. *In Geography.*—Let the diagram represent the earth; and let the point marked "zenith" represent the position of the observer—the point marked "nadir" representing that of his antipodes. Then the hour circles will become meridians, with angular intervals each representing 15° of longitude; the parallels of declination will be parallels of latitude; the parallels of altitude will be parallels of distance from the observer; and the vertical circles will be the "great circles" of the navigator.

5. In the diagram the latitude is supposed to be 56° north. The 56th parallel crosses Scotland a few miles to the north respectively of Edinburgh, Glasgow, and Greenock. The planisphere itself is about nine inches in diameter.

Improvements in Couplings for Railway Carriages. By James Mackenzie, Manager's Department, North British Railway.*

Before proceeding to describe this contrivance, I may state that the form of it, of which I have provided drawings, is that intended for goods and mineral waggons, and not for passenger carriages. It can be adapted to the latter, but at present I do not propose to extend the use of it to that class of railway vehicles.

Any one who has observed the process of arranging trains of waggons at any of our railway stations, must have seen

* Read before the Society 28th March 1870, and awarded the Keith Prize value Thirty Sovereigns.

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MACKENZIE'S APPARATUS FOR CONNECTING AND DISCONNECTING RAILWAY WAGONS BY MEANS OF THE ORDINARY COUPLING LINKS.

Fig 1

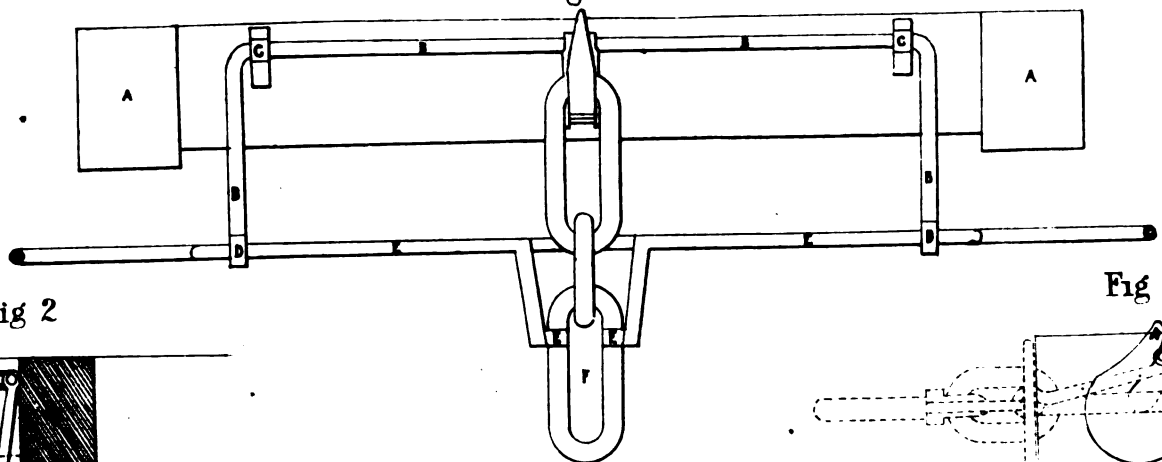


Fig 2

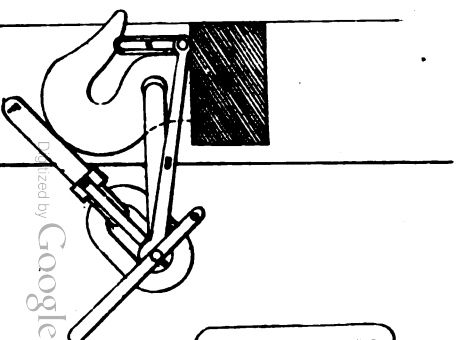


Fig 3

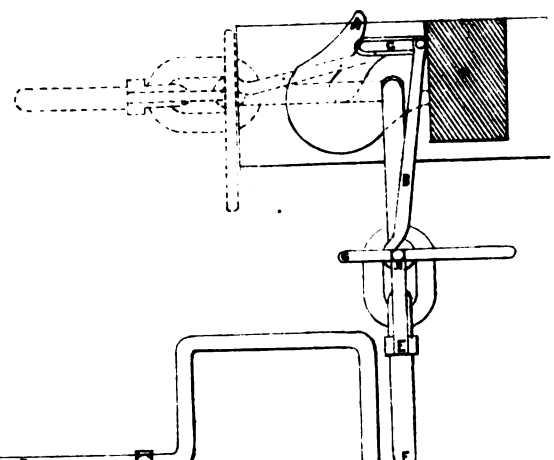
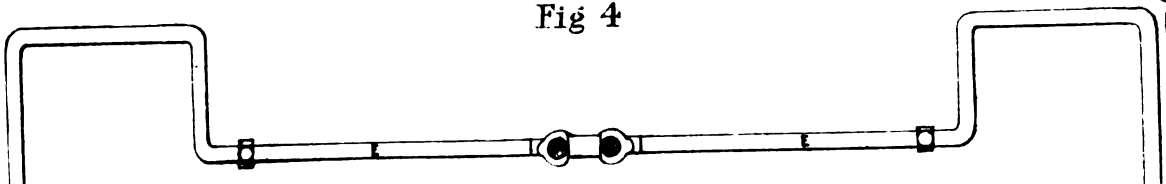


Fig 4



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that the men engaged incur very great risk of accident. In effecting the connection of one waggon with another, the man has to creep in under the waggon ends (if they be in contact), or get in front of the waggon, and hold the coupling-links until the waggon to be attached is propelled toward him. He then puts on the coupling, and has to creep out under the waggon ends, the waggons being very probably in motion by the time he does so. A slip in such a case might be fatal; but, indeed, however careful the man may be, he may be *thrown* down,—an accident which has frequently happened from contact with the inside buffer beams used upon one class of waggons, which beams need not at present be described. The operation of disconnection is perhaps even more dangerous, because it is so commonly performed when the waggons are in somewhat rapid motion. The man runs alongside, until he has an opportunity of vaulting upon the buffer beam of the waggon. He then reaches over, supporting himself as he best can, and releases the link by hand. In the event of any sudden check to the train, he runs an extreme risk of being jerked off the beam, his hold being very insecure, and the result may be easily conceived. Between these two operations more accidents are caused than by all the other duties required of the men, put together. I have here a letter from Mr Hunter, who acts as secretary to an insurance society maintained among the servants of the North British Railway Company, in which he states, that of the accidents which happen to the men connected with the Goods' Department, the enormous proportion of 90 per cent. occur to those engaged in the coupling and uncoupling of waggons.

But the dangers of these operations have been long too well known, and many inventions have been brought forward to effect the required end with safety. I had occasion to be in the Patent Office in London some time ago (with the view of ascertaining, if possible, whether or not any plan similar to this had been heard of before), and I came upon a considerable number of specifications of inventions for the same purpose. I found that they all (with one exception)

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required that before the advantages of the particular system could be realised, the present coupling be abandoned, and the one proposed substituted; and not only this, but the present waggon stock would require to be brought as nearly as possible to one uniform standard. The fulfilment of the latter condition I would hold to be impracticable, not only on account of the mixed stock already in the possession of the railway companies, but also on account of the constant interchange of waggons of differing proportions over all the railways in the kingdom.

Now, the view I take of the matter is this:—before the adoption of any plan could be entertained, it would be essential—1, that it be simple; 2, that it be as inexpensive as possible; and 3, that it be capable of being worked along with other waggons, whether they be fitted with it or not—in other words, that it be capable of *gradual introduction.* I therefore, in the meantime, do not propose any alteration upon either the present waggon or coupling. I merely affix to the waggons as they stand at present the apparatus which I shall now describe.

The first figure represents an end view of a waggon, with the coupling apparatus attached. The waggon frame is tinted light brown, the present drawhook and coupling blue, and the proposed apparatus is shown in black.

The horizontal rod, *a*, is slung to the breast beam of the waggon by the brackets, *bb*, the ends of the rod being bent downward. Each of the bent-down ends is at its extremity turned over so as to form a loop or eye, *cc*, through which are passed a pair of rods, *dd*, running parallel to the first, which rods are also bent downward on each side of the coupling, and are made to grasp the lowest link. At their junction with the upper rod, at *cc*, they are prolonged and bent so as to form on each side of the waggon a lever or handle, *ee*, giving the required "purchase."

Fig. 2 will show the action of the apparatus. The positions when uncoupled and when under strain are both shown in the one figure. To connect one waggon with another, the man grasps the handle *e*, and by lowering the one end and raising the other, he brings the end link into the posi-

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tion shown in fig. 3. He has then only to guide the link to the hook, by swinging the whole apparatus in the proper direction. The upper rod is thus brought into action, and *reaches* the link as far as may be required. Disconnection is, of course, the reverse movement, and can easily be effected with one hand. The mere pulling up of the handle at the elbowed portion, *a* (fig. 4), lifts the link over the top of the hook, and the coupling falls by its own weight.

It will be seen that the action exactly resembles, and indeed is taken from, that of the human arm—the bent down portions of the upper rod, *a*, corresponding to the *humerus*, and those of the lower rods, *dd*, to the forearm and hand. From this arm-like action, it is immaterial whether the waggons be relatively high or low framed, short or long in the frame ends, or spring or "dead" buffered.

It may be objected that the adoption of the proposed arrangement would involve too great expense; but I may safely say that, in comparison with any others I have seen, it would be far from costly, and that, if any railway board were to entertain the idea of applying any apparatus of the kind, or if the adoption of a safety coupling were made compulsory, the *least* expensive system would be most likely to be favourably considered. The cost of this apparatus has been estimated by several practical engineers and mechanics at about fifteen shillings per waggon, both ends fitted complete.

It may also be objected that it is liable to be injured by carelessness on the part of the men themselves. But surely the men could be persuaded to take some little care of what is provided entirely for their own safety; and further, although "two blacks do not make one white," there is hardly a possibility of producing any appliance for the same purpose which would not be liable to the same objection.

No one will doubt, I daresay, the great necessity there is of adopting measures of some kind to impart greater safety to the duties of our railway servants. It is painful to think of the sufferings of those unhappy men who may have been injured and yet survived, and the misery brought upon the poor families of those who have been mortally injured.

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On an Equal-Surface Projection for Maps of the World, and its Application to Certain Anthropological Questions. By Professor C. Piazzi Smyth, Astronomer Royal for Scotland.*

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* Read before the Society 9th May 1870, and awarded the special thanks of the Society.

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Part I.

I. INTRODUCTORY STATEMENT.

In the present advanced and continually developing times in which we live, there is more and more occasion every day, not only in geographical and political, but also for meteorological, magnetical and many other scientific inquiries, to refer to maps representing the whole world at one view and in the most *equal* possible manner.

Now the usual projection of the sphere employed on such occasions is, almost invariably, that well-known one of *Mercator's*. A very admirable projection too it is for a great variety of purposes and yet not altogether suitable to that special end of entirety and equality which I have just mentioned.

Of that end, Mercator's projection falls short, because—

1st, It never is and never can be a projection of the *whole* world's surface, seeing that that would require a sheet of paper infinitely large from north to south, though ever so narrow from east to west. In practice therefore the so-called "World on Mercator's projection" is cut off at a variable latitude in either hemisphere according to the taste of each different map-maker; some of whom give no more than 80° of the Northern, and 65° of the Southern, Hemisphere; or a very partial and sadly lopsided view of the world as a whole.

2d, It exaggerates the *apparent sizes* of the Polar, over the Equatorial, portions of the world to a degree beyond the power of the mere eye and judgment to correct at every step.

These two grand disadvantages, however, may be instantly eliminated, by simply representing the latitudes as *sines* upon an otherwise Mercator's projection;* and adopting at the

* I have mentioned the idea in several quarters during the last three years, but without being able to get any one to take it up and produce such maps for general use; nor have I come across anything like it, even on looking

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same time the *arc* length of 90° for the radius or straight meridianal distance from the Equator to the Pole; for then we have, not only the very Poles themselves definitely included on the paper, but the areas of parts between different latitude parallels and longitude meridians made of the same proportions as on a true sphere: while the distortion, which is inherent in every representation of any sphere's surface on a plane, is nearly confined to a flattening of the extreme Polar regions; for at 50° 13′ of latitude the proportions of latitude and longitude degrees are true, and below that, though there is an extension in latitude, it is comparatively slight.

2. *Practical Construction.*

To construct these maps,—having settled the length to be given to the Equator, take half that for the meridianal height from Pole to Pole. Half that length again multiplied by the sine of any latitude will give the distance of its parallel from the Equator; while the longitude meridians will be represented by equidistant lines at right angles through these parallels.

For the benefit of those who have not a table of natural sines at hand, I supply these quantities for every 5° of latitude, and for several different linear sizes of maps.

A map constructed on this plan is shown in Plate IV. (see Plate VII.), deduced by myself with care from several large Mercator's maps; but which, though by certain of the first authorities at present existing in London and Edinburgh, differ from each other in details of various countries more than might have been expected.

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through many approved modern atlases, and inquiring at most of the leading map-sellers and geographers in both London and Edinburgh. Yet so simple a construction for procuring so great an advantage as "equal-surface" can hardly but have occurred to other minds also; and I hold myself ready to acknowledge the cases whenever they may be brought to light.

Second Note, at a later date.

See such a result in the second note to pp. 195, 196.

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TABLE I.

Linear Distances for Construction of Equal-Surface Projections of the Sphere.

Assumed Length of Equator =	4·00	14·00	16·00	20·00	24·00	28·00	40·0000
Distance Pole to Pole =	2·00	7·00	8·00	10·00	12·00	14·00	20·0000
Latitude.							
0°	0·00	0·00	0·00	0·00	0·00	0·00	0·0000
5	0·09	0·30	0·35	0·44	0·52	0·61	0·8716
10	0·17	0·61	0·70	0·87	1·04	1·22	1·7365
15	0·26	0·91	1·04	1·30	1·55	1·81	2·5882
20	0·34	1·20	1·37	1·71	2·05	2·39	3·4202
25	0·42	1·48	1·69	2·12	2·54	2·96	4·2262
30	0·50	1·75	2·00	2·50	3·00	3·50	5·0000
35	0·57	2·01	2·30	2·87	3·44	4·02	5·7358
40	0·64	2·25	2·57	3·21	3·86	4·50	6·4279
45	0·71	2·47	2·83	3·54	4·24	4·95	7·0711
50	0·77	2·68	3·06	3·83	4·60	5·36	7·6604
55	0·82	2·87	3·28	4·10	4·91	5·73	8·1915
60	0·87	3·03	3·46	4·33	5·20	6·06	8·6602
65	0·91	3·17	3·62	4·53	5·44	6·34	9·0631
70	0·94	3·29	3·76	4·70	5·64	6·58	9·3969
75	0·97	3·38	3·86	4·83	5·80	6·76	9·6593
80	0·99	3·45	3·94	4·92	5·91	6·89	9·8481
85	1·00	3·49	3·98	4·98	5·98	6·97	9·9620
90	1·00	3·50	4·00	5·00	6·00	7·00	10·0000

3. *General Uses of the Map.*

As a first practical example of the uses of such a map, let us take a case of extreme puzzle from Mercator.

In Mercator's projection of the world, Africa is a very notable sized country; no wonder therefore it has filled a third of the earth with its irrepressible negroes, its fame, its woes, and its varied wealth! But what is this other country, something of the same shape and *in Mercator* as big, yet with no such history or influence connected with it?

It is actually Greenland. Greenland which has in truth only *one-thirtieth* part of the area of Africa. That, at least, the real proportion on the globe, and you see here on *our Plate IV.* (or VII), how nearly that proportion is there preserved.

Again when studying the nature of those many things which go by *surface* on the world, what latitude parallels

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are so important as those of 30°; for they subdivide into two equal extents of surface either hemisphere! Yet in the *Mercator* see what a miserably contracted breadth is that zone between the Equator and 30° latitude; and how magnificently superior in apparent extent is the really smaller portion of the world between 30° and 80° of latitude. The difference is in fact enough, if not entirely to warp the judgment of both old and young—at least to give them a trouble in applying large numerical corrections which they will not have with an *equal-surface projection;* for there, as in our Plate IV. or VII., the latitude parallel of 30° does exactly evenly subdivide the space between the Equator and either Pole.*

These considerations, however, will have been prominent enough also to any possibly earlier devisers of *equal-surface* map projections, as already indicated. Let us hasten on therefore to some further applications, where I trust we shall not only be doing useful work, but touching at last on some original as well as important ideas.

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* I have recently seen a map published only last summer, and stated to be "according to *Gall's* new projection of the sphere on a cylinder, distorting the form of the continents less than that of Mercator and giving more importance to the equatorial and temperate regions of the globe."

These remarks show that Mr Gall must have perceived very similar failings in Mercator to what I have described, but he has only *partly* corrected them: for his degrees of latitude increase in length from Equator to Pole in the proportion apparently of 1 to 2. Hence Mr Gall's Polar countries have always far too large a surface as compared with Equatorial ones; and if the difference is not so extravagant as with Mercator, Mr Gall loses the correctness of angles intermediate between the cardinal points.

Note Second, of later date.

Subsequently to writing the paper and its above note, and to their both being read at the Royal Scottish Society of Arts,—I have been informed, that so far back as 1855, the Rev. James Gall, jr., the gentleman above alluded to, described before the British Association at Glasgow, among three different projections of the sphere, an "equal-surface" one; and claims that he is now, July 1870, *going* to publish it;—wherefore I can but most cordially wish him all success in persuading the public to adopt it in preference to his already published "Gall's projection," which is neither an *equal-surface* one, nor a sailing one, but a rather confusing nondescript as just indicated.

Equal-surface projections of the sphere were, however, on the recent showing of Professor Fleeming Jenkin, by no means new, even for much earlier periods than 1855; though he allows that they have fallen into unmerited neglect and oblivion both with map-makers and the public for many years past: more so however at home than abroad, for the Professor of Civil Engineering quotes

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4. *Application to the Earth's Surface Temperature.*

Plate V. represents on an *equal-surface* projection the isothermals of the earth's surface temperature, in degrees Fahrenheit, at the level of the sea, and chiefly as gathered by the long and honourable labours of Professor Dove.

These same curves, when inscribed on a Mercator's map, give the uncomfortable impression of the greater part of the earth's surface having a mean temperature below 32° Fahr., or freezing to an extent nearly impossible to human existence. But an equal-surface map shows that the medial portions of the earth's surface in either hemisphere, or along 30° of lat., enjoys the very comfortable temperature of nearly 68° Fahr.; and that there are about equal surfaces on one side higher (indicated by red shading), and on the other lower, in temperature (indicated by blue shading).

Also, that between the isothermals of 10° above and 10° below 68° Fahr., there is comprised a far greater portion of the earth's surface than between any other isothermals of equal thermometrical distance apart.

Evidently, then, the temperature of 30° parallel of latitude, as being at or near 68° Fahr., is the *ruling* temperature of the human world: not the exact mean temperature of its whole surface, because the fall in Polar, is greater than the rise in Equatorial, regions: but if we omit those extreme Polar areas, which are totally uninhabited by man, then 68° Fahr.

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a good French atlas by the learned academician M. Babinet, purposely on an *equal-surface* projection.

My search therefore after possible predecessors might, and perhaps ought, to have been more thorough. But my object was entirely practical; and when I could not find such a map to purchase in any shop and required it in an investigation already commenced (and would not have been aided therein by merely finding that the *idea* had been invented even many centuries earlier), — I simply sat down and made one, and lithographed it also for the benefit of others as well as myself.

For this I trust that I shall not be very seriously blamed, especially when withdrawing, as I am most happy to do, the remotest claim for originality of invention, and not attaching importance even to the independence of idea and working out, which were undoubtedly present in this case; and wherein, if I had not done precisely as I did, I could not *then* have gone on to the other and more advanced questions discussed towards the close of this paper.

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is very nearly indeed the mean temperature of all the rest of this our earth which is occupied by, or is useful to, or is essential for the existence of, man. Whenever, or wherever the temperature rises above that height, we find nations occupied in protecting themselves from heat and cooling their abodes; and when below that happy mean, they are as intent on lighting fires in their houses and wrapping warm clothing about themselves whenever they venture abroad.

An equal surface map then tends to bring the peculiar thermometrical importance for anthropology of the parallel of 30° into distinct and prominent view: and, that its average mean temperature all the world round *is* something remarkably close to 68° Fahr., I beg to subjoin in Appendix I. some new and independent observations.

5. *Application to Lines of Barometric Pressure.*

On Plate VI. are exhibited the lines of mean annual barometric pressure of the atmosphere at the level of the sea, as compiled with great labour by Mr Buchan, the excellent Secretary of the Scottish Meteorological Society, and published in the Transactions of the Royal Society of Edinburgh, vol. for 1867–8.

Over and above however being here translated from the Mercator's, into an *equal-surface*, projection,—the speciality is attempted of reducing the barometric pressure in inches of mercury, not to the freezing point,—where no man observes his barometer; but to that admirable mean temperature already proved to be of all men's experiences on this earth, viz., 68° Fahr.; and I would take the present opportunity of recommending the principle, both as the more natural one and that least affected by any residual uncertainties in our knowledge of the expansion of mercury.

The general result for the parallels of 30° lat. in barometric pressure is,—that its mean amount is rather large; being 30·09 in the northern, and 30·06 inches in the southern, hemisphere; but accompanied with the feature of long, *i.e.*, slow, pressure gradients, indicating therefore a comparative

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immunity from the destructive storms of most other parts of the earth.*

6. *Application to the World's Land and Sea Surface.*

The relative amount of sea and land surface over the whole globe is a datum very frequently demanded of geographers; and an *equal-surface* map is so conveniently adapted for obtaining a new and unbiassed numerical esti-

* The following letter, received from Mr Buchan while passing the above paper through the press, will be read with interest for the important and weighty opinions of its author on the above subjects; subjects long professional with, and thoroughly studied by, him:—

"SCOTTISH METEOROLOGICAL SOCIETY,
GENERAL POST OFFICE BUILDINGS,
Edinburgh, 21*st October* 1870.

"DEAR SIR,—You are most welcome—indeed, with thanks—to my tables and charts of pressure.

I quite agree with you that other temperatures are to be preferred for reduction than 32° F.—such, for example, as that adopted by the Russians, 62° (13°.3 R.), which nearly approaches the mean temperature of the globe, a temperature which is perhaps the most comfortable for human beings.

We received some time ago a complete set of the Annals of the Austrian Meteorological Society. These give meteorological data for five years for Cairo. I send you the thermometric and barometric means for these five years, since doubtless they will interest you.

It is curious to see that the barometric observations, reduced to the mean temperature of the place, give 30 inches exactly as the annual mean. It would be very interesting if from these data it followed that the mean annual pressure inside the Great Pyramid, at the mean temperature *there*, was also 30 inches.

The means of the months for the mean of the five years are as below.—I am, yours truly, ALEXANDER BUCHAN.

PROFESSOR SMYTH.

"Mean temperature and mean pressure of the atmosphere, reduced to 32°, but not to sea level, at Cairo, Egypt, 30° 2′ lat. N., 48° 55′ long. E. of Ferro; height, 96 feet (15 toises).

	Jan.	Feb.	Mar.	April.	May.	June.	July.
Mean temperature...	53°·3	55°·6	61°·1	70°·0	77°·3	81°·3	83°·7
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Mean pressure.....	29·974	30·024	29·934	29·870	29·841	29·809	29·727

	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean temperature...	83°·7	76°·4	73°·1	66°·1	56°·8	69°·9
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Mean pressure.....	29·750	29·884	29·936	29·956	29·960	29·889

Mean pressure at temperature 69°·9 = 30·000 inches.

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mate, that I have tried it for that end in the following manner.

In the first place to obtain the relative land and sea surface in similar zones all over the world, I decided on having *ten* equal surface belts parallel to the Equator, in either hemisphere; and then computed their limiting parallels of latitude, together with their middle latitudes, as in the following Table II. (There is also inserted there the length of a degree of longitude in each of these latitudes, but that is only intended to come into use in a subsequent enquiry.)

Table II.

Latitudes of Equal-Surface Zones, either on the Sphere or the Equal-Surface Projection.

Subdivisions in Terms of Distance from Equator to Pole = 1.	Latitudes.	Length of Longitude Degrees in same Latitude.
	° ′	
·00	0 0	608
·05	2 51	607
·10	5 44	604
·15	8 38	601
·20	11 33	595
·25	14 29	588
·30	17 27	579
·35	20 29	569
·40	23 35	557
·45	26 45	542
·50	30 0	526
·55	33 22	508
·60	36 52	486
·65	40 32	462
·70	44 26	433
·75	48 36	402
·80	53 8	365
·85	58 12	320
·90	64 9	265
·95	71 48	190
1·00	90 00	000

"Hours of observation for temperature and pressure—6 A.M., 2 P.M., and 10 P.M., of which the above are the means.

The observations began in January 1857, and were continued till December 1861. Thus the averages are for five years.

Months omitted—1857, June; 1858, February and September; 1859 August. The rest are complete."

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Taking next each of the zones in small rectangular portions, or by ten degrees of longitude at a time, it became comparatively easy in so diminutive a superficial extent (or $\frac{1}{720}$th of the whole map) both to decide by eye on the comparative amount of land and sea-surface there included, and to represent them by meridian subdivisions of each said rectangular space of zone. Then by blackening each *water* compartment and leaving the land white, series of rectangles of a uniform height were formed in every zone, the sum of the breadths of whose white members gave the land, while the sum of the breadths of the black ones showed the water, surface.

Proceeding afterwards similarly, but *mutatis mutandis* for longitude map-columns transversely divided at small intervals of latitude, there were obtained at last the two following Tables III. and IV.:—

Table III.

Land and Sea relative Surfaces in successive Parallels of Latitude, so chosen as to define in either Hemisphere Ten Equal-Surface Zones.

Number of Zone from North to South.	Its Middle Latitude.	Measured Surface of		Sum.
		Land.	Sea.	
1	71° 48′ N	4·78	9·22	14·00
2	58 12	8·00	6·00	14·00
3	48 36	7·27	6·73	14·00
4	40 32	6·29	7·71	14·00
5	33 22	5·95	8·05	14·00
6	26 45	5·43	8·57	14·00
7	20 29	4·63	9·37	14·00
8	14 29	3·50	10·50	14·00
9	8 38	3·43	10·57	14·00
10	2 51 N	3·22	10·78	14·00
11	2 51 S	3·38	10·62	14·00
12	8 38	3·34	10·66	14·00
13	14 29	3·12	10·88	14·00
14	20 29	3·45	10·55	14·00
15	26 45	3·14	10·86	14·00
16	33 22	1·80	12·20	14·00
17	40 32	0·72	13·28	14·00
18	48 36	0·33	13·67	14·00
19	58 12	0·14	13·86	14·00
20	71 48 S	0·32	13·68	14·00
Sums,	...	72·24	207·76	...

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Table IV.

Land and Sea relative Surfaces, in successive Meridian Intervals of Longitude; and for every Ten Degrees of the same.

Number of Meridianal Interval,	1	2	3	4	5	6	7	8	9	10	11	12	
Its Mean Longitude, . . .	145° w	135°	125°	115°	105°	95°	85°	75°	65°	55°	45°	35°	
Land Surface, .	0·23	0·30	0·78	1·56	2·03	1·67	1.60	3·05	3·40	2·50	1·57	0·50	
Sea Surface, . .	6·77	6·70	6·22	5·44	4·97	5·33	5·40	3·95	3·60	4·50	5·43	6·50	
Sum, ...	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	

Number of Meridianal Interval,	13	14	15	16	17	18	19	20	21	22	23	24	
Its Mean Longitude, . . .	25°	15°	5° w	5° E	15°	25°	35°	45°	55°	65°	75°	85°	
Land Surface, .	0·27	0·82	2·10	2·31	3·87	4·54	3·95	3·08	1·88	1·80	2·28	2·18	
Sea Surface, . .	6·73	6·18	4·90	4·69	3·13	2·46	3·05	3·92	5·12	5·20	4·72	4·82	
Sum, ...	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	

Number of Meridianal Interval,	25	26	27	28	29	30	31	32	33	34	35	36	
Its Mean Longitude, . . .	95°	105°	115°	125°	135°	145°	155°	165°	175° E	175° w	165°	155°	Sums.
Land Surface, .	2·48	2·83	2·95	2·54	2·18	2·14	0·70	0·64	0·42	0·12	0·15	0·36	65·78
Sea Surface, . .	4·52	4·17	4·05	4·46	4·82	4·86	6·30	6·36	6·58	6·88	6·85	6·64	186·22
Sum, ...	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	7·00	

Hence we draw the conclusion that Table III. indicates the whole land-surface of the world to be to its sea-surface as

1 : 2·876

and that Table IV. indicates the proportion of the same surfaces to be

1 : 2·831.

The difference between the two determinations is caused

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by unavoidable small errors, and inasmuch as I do not know any reason for considering one of them either better or worse than the other, the mean between the two will be the safest conclusion to employ, viz.,

Land-surface of globe, . .	= 1
Sea-surface, ...	= 2·854

Now, the generally received numbers given in that very well edited book, Dr Mackay's Geography (1869), render a proportion of 1 : 2·825, or seem to require a sensible correction.

7. *Special Application to Earth's "Centre" Question.*

Throughout all the days of history, there has been no small rivalry among certain nations in asserting that *their* portion of the earth was the most important of all the world's surface; for their country, each such nation would persist, was in no less distinguished a position than the very *centre* of that surface, while other countries were merely at *the borders* thereof.

Hence, with so self-asserting a people as the classic Greeks, no wonder they were found clenching the conceited *dictum* in their case, by showing at Delphi the very *omphalos* or navel-stone of the whole earth; proof positive in Greek estimation of *their* absolutely central and vital position. And, perhaps, not less wonder in recent times that the *savants* of modern London, though living in a totally different latitude and longitude, have equally shown proof, most convincing to *themselves*,—that if you take compasses and describe on a globe a circle including, as they say, "all the land surface of the world," the city of London (some say Liverpool) is in the centre of that circle!

The main idea built upon in either of these cases, is in its origin the very sound doctrine, that human empire depends essentially on the possession of land, as opposed to sea, surface in the world. And it is sound because, man can live and multiply on the land but he can do neither in the sea. And though very eloquent praise is occasionally extended to the distribution of land with intervening sea-surface as

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the greatest of national advantages, there *are* political economists who declare even that to be a mistake; for how would it promote economy in working a farm, if its every acre, instead of being juxta-posed, were separated from every other by several hundred miles in breadth of stormy sea between. While, when it comes to war, real, uncompromising destructive war between two races or nations, the one who can go on outnumbering the other on every successive battle-field is sure to win in the end.

Inhabitable land surface therefore is a necessary foundation for national greatness; and happy that people which has most of it and in those parts of the earth where men both can, and do, chiefly congregate and flourish; that is to say, not only in the general mechanical and material centre of the whole surface, but where the temperature is likewise most nearly a mean between the hotter and colder parts of the earth, and the facilities for communicating with distant regions are most direct and emphatic.

To examine seriously on all these counts the result of the Grecian sages, who were acquainted with only a wretchedly small portion of the whole world, and never possessed a thermometer amongst them, would be cruel; but the London case *ought* to bear the closest scrutiny of modern science. Not, however, that it offers any sensible resistance; for while it breaks down under the *thermometrical* test immediately, it may be still more seriously objected to under the two following heads; viz.—

1*st*, New Zealand, Australia, and certain parts of America —though abundantly inhabited by the Anglo-Saxon, as well as other races of mankind—are coolly left out of the circle (London's land-hemispherical containing circle) as not suiting its arbitrary sweep;—and,

2*d*, Because the North Pole is still more coolly and even audaciously *included* therein.

"Audaciously," because that North Polar region has never yet been reached, or taken possession of, by any man, though striven for through ages.* And as it owes largely those

* Hast thou entered into the treasures of the snow? or hast thou seen the

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superhuman antagonisms which it possesses to the axial rotation of the globe—and that, not only one of the most enduring physical features of the *cosmos*, but the one on which man's life on other parts of the earth, and the very conditions of his existence, mainly depend—it would seem to be but decent respect to the Author of all, that any measurement of the earth's land surface for human glorification, for exemplifying man's empire and national fame, should be taken in visible deference to, and practical acknowledgment of, that Divinely imparted rotation of the whole earth-ball on its axis: or, in other words, should be carried out in zones and sections bounded by latitude parallels, and longitude meridian lines.

Now that is precisely as we have just performed a necessary part of the problem on our equal-surface projection. Referring therefore to the numbers given in Tables III. and IV., it will be perceived that they make the land surface towards the north to be exactly equal in extent to the land surface towards the south on either side of a certain latitude parallel: and that is not the parallel of London (where the proportions N. and S. are 13 to 59), no, nor yet of Delphi (where the proportions are 24 to 48), but of the far more southern latitude of 25° 30′ N. (where the proportions are 36·12 to 36·12, as see the line A, A, on Plate VII.).

While the world's same total land surface towards the west is equal to that towards the east, on either side of the longitude meridian of either 29° 5′ E., or 150° 55′ west (see the lines B, B, and b, b, on Plate VII.); giving therefore two crossing points with the latitude parallel for the *land centre* of the earth's surface, but in neither case falling either on London or Delphi.

8. *Limits of Longitude of that Earth's surface Land Centre.*

There are indeed now before us two opposing longitudes just 180° apart; but we need be under no difficulty in making a choice between them; for while the meridian of

treasures of the hail; which I have reserved against the time of trouble, against the day of battle and war.—Job. xxxviii. 22 and 23.

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150° 55′ west traverses little or nothing but sea through its whole course from pole to pole, the meridian of 29° 5′ east passes over much more land than sea, and cannot be ignored.

Not only too does a general maximum of land-surface in many adjacent meridians come, together with the "dividing meridian," near to 29° E.,—but the particular maximum of linear meridian length of land, as measured on a globe, appears to fall so near thereto as on 25° E.; while another and very important anthropological datum occurs at 35° E.

This last datum is the meridian wherein the maximum development of genial terrestrial surface-*temperature* takes place; a feature which is but another consequence of the distribution of land and sea-surface over the world, as shown by the researches of the late Principal Forbes.*

Hence if we sum up in the several 10 degree longitude spaces of Plate V., the various temperatures in the 20 equal-surface zones of latitude from north to south, or in the 18 only inhabitable zones from 71° 48′ north to 71° 48′ south,—we have the following numbers, both sets of which indicate a maximum mean to be connected with 35° of longitude East.

TABLE V.

Development of Terrestrial and Surface Temperature in Successive Longitude Spaces.

Mean longitude of space,	5° E.	15°	25°	35°	45°	55° E.
Pole to Pole, . . .	60°·5 Fah.	61°·0 Fah.	61°·1 Fah.	61° 2 Fah.	61°·1 Fah.	60°·6 Fah.
71° 48′ N. to 71°·48′ S., .	65·8	67·6	68·0	68·8	68·3	66·9

Hence there are three, if not four, separate results all pointing to a meridian between 25° and 35° East, as having the honour of marking, or including, the longitude Meridian of the only unexceptionably measured centre of all the inhabited and inhabitable land surface of our globe.

* See Appendix I., p. 219.

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(9.) Limits of Latitude of the same Centre.

But what is also the latitude of that centre?

We did indeed obtain one result for it, by finding that the dividing parallel of the earth's land-surface was in 25° 30′ N.; but there are various German geographers in the field, declaring that both the old and new continents (the former including Africa, Asia and Europe, and the latter comprising the two Americas only) have, *each of them*, their greatest breadths of land-surface in the latitude parallel of 50° north: and such land breadth is precisely a most important element to be taken into account in our inquiry.

What the methods of computation in use among the German geographers may be, I have not been able to learn, but I can set forth before this Society, and render amenable to its criticism, what my equal-surface projection map has already given forth on the matter.

Trying, then, first of all latitude land-breadths in our 20 equal-surface zones (each such zone being nearly equivalent to taking a mean of all the variations in every 500 miles of meridian),—and multiplying the map breadth of land in each by the value of its mean degree of longitude as given in Table II., we obtain the absolute breadth of land in each such zone, as though it were measured on a globe; and then find —in spite of the German geographers—that *neither* continent has its greatest latitude breadth in 50° N. For that quality in the old world is in 26° 45′ N., and in the new, is not in any part of the northern hemisphere at all, but in 8° 38′ south;* while the mean of the two continents, *i.e.*, all the land-surface of the earth, gives the zone of greatest land breadth as 33° 22′ N.; or in accordance with the following Table VI.

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* America does *tend* to spread out near 50° N. latitude; and accomplishes it, partly by intercalating into its continental area large fresh water lakes, and the almost land-locked salt sea of Hudson's Bay, and partly by both extending out Nova Scotia and pushing out Newfoundland even away from itself still further into the Atlantic. But if we rigorously eliminate all these water spaces, the residual land surface alone, is, as stated above.

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Table VI.

Relative Latitude Breadths of Solid Land-Surface in the E.-S. Zones.

Number of Zone.	Middle Latitude.	Old World, or Europe, Asia, and Africa.	New World, or America.	Both together, or all the Land-surface of the Globe: by an independent determination.
1	71 ° 48′ N.	·48	·43	·91
2	58 „ 12	1·72	·84	2·56
3	48 „ 36	2·07	·85	2·92
4	40 „ 32	2·02	·88	2·91
5	33 „ 22	2·20	·82	3·02
6	26 „ 45	2·55	·39	2·94
7	20 „ 29	2·26	·37	2·63
8	14 „ 29	1·84	·22	2·06
9	8 „ 38	1·67	·39	2·06
10	2 „ 51 N.	1·32	·64	1·95
11	2 „ 51 S.	1·18	·87	2·05
12	8 „ 38	1·00	1·00	2·01
13	14 „ 29	·99	·84	1·83
14	20 „ 29	1·31	·65	1·96
15	26 „ 45	1·21	·49	1·70
16	33 „ 22	·57	·34	·91
17	40 „ 32	·12	·21	·33
18	48 „ 36	·03	·10	·13
19	58 „ 12	·00	·04	·04
20	71 „ 48	·06	·01	·06

Next, if the meridian depth of the stripe of land summed up in latitude parallel or breadth all round the globe, be made very small,—then my friend William Petrie discovered quite independently of me, and three years ago—that the greatest of such latitude-breadth of land-surface is in 30° N.,—subject to an uncertainty of a few miles either way connected with the errors and differences of all the best maps and globes he could procure in London.

Hence the advocates for the broadness of land in Lat. 50° N. are left (so far as I can see), without any support; while, on the other hand our previously arrived at latitude parallel of the general land-centre of the globe, or 25° 30′ N., has received two near geographical confirmations, viz., 33° 22′ N. and 30° N.; and is likewise found to be located close to one of the *mean-temperature* belts of all inhabited lands, *i.e.*, 30° latitude, as indicated on page 198. A remarkable and

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perhaps unexpected result too is this last; and one which could not have happened but for the very unequal distribution of land in the two hemispheres N. and S.; for otherwise the land centre must have fallen on or near to the equator, that is on the very maximum of the heat scale.

10. THE EARTH'S SURFACE LAND CENTRE FOR THE HUMAN PERIOD GEOGRAPHICALLY APPROXIMATED TO.

In fact where our three lines in longitude and three in latitude cross (as on Plate VII.), there is not only now, but there also has been, for man, in and through all his history, *the centre of the earth* in the ancient manner of speaking: or, in our modern language, the centre of the earth's whole land-surface, the ruling temperature of the inhabited globe, and the most remarkakle instance all the world over of almost mean atmospheric pressure combined with slow gradients of change—which means a happy immunity nearly from whirlwinds, hurricanes, and storms.*

And all this throughout the whole human period, past and present if not also to come; for, though land may be rising out of the sea in one part of the world and sinking under it in another, there are no records tending to show, and no reasons to conclude, that it has, during the last 6000 years changed on the whole to any sufficient extent for sensibly displacing the newly proved *central land point* out of the limits of that very little square of intersections,—or closer still, that smaller inscribed triangle formed by the crossings of the three pair of co-ordinates,—drawn on Plate VII.

That small triangle contains therefore, by this our first approximation, the veritable terrestrial seat of the centre of all anthropological interests, favourable influences and human empire on earth, throughout all anthropological time; *i.e.*, ever since intellectual and religious man appeared on the scene and thereby produced an epoch in the history of the earth without any previous parallel, and earlier than which there are no sufficient interests to compare with ours.

* The region is also nearly, though not entirely, free from earthquakes and has been so during long past ages.

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In the long previous geological ages, no doubt the distribution of land and sea-surface was occasionally very different; and some of the animals then existing and feeding themselves may have been, according to certain of their recent apologists, endued with no little amount of cleverness and even some reasoning power; but which of them has ever been proved to have begun to seek after God, or to call upon the name of the Lord;—*i.e.*, as man began to do 6000 years ago, and is not shown to have done earlier, and will never cease doing so long as he remains upon the earth.

Part II.

11. LONGITUDE REFORM FOR THE PRESENT TIMES.

Yet if we were to stop at this point, or with mere improvements of certain data attempted to be given in most school books on geography and classical history,—we should have accomplished little directly meriting the attention of a practical scientific Society like our own. Is there nothing therefore to be deduced for the benefit of grown men in the world and for their everyday business in life?

There *is* something of that nature, and connected so immediately with the foregoing as a corollary, that I trust the Society will bear with me for a few minutes longer while I endeavour to give members an idea of it.

Who is there then, with much experience of maps by the rival nations of Europe, who does not find reason to regret the diversity of *longitude zeros* in use among them.

Britons generally are worthily loyal in reckoning all their longitudes, from that admirable Observatory which has done more for longitude, than all other institutions in the country; viz., Greenwich.

Frenchmen are enthusiastic in reckoning all their longitudes from Paris, and are followed by some Germans, as well as, I fear, by a few of those English who are rather over fond of French measures in other matters also.

Spain, with an imperturbable dignity of reliance on past glories, persists in reckoning from the meridian of Cadiz.

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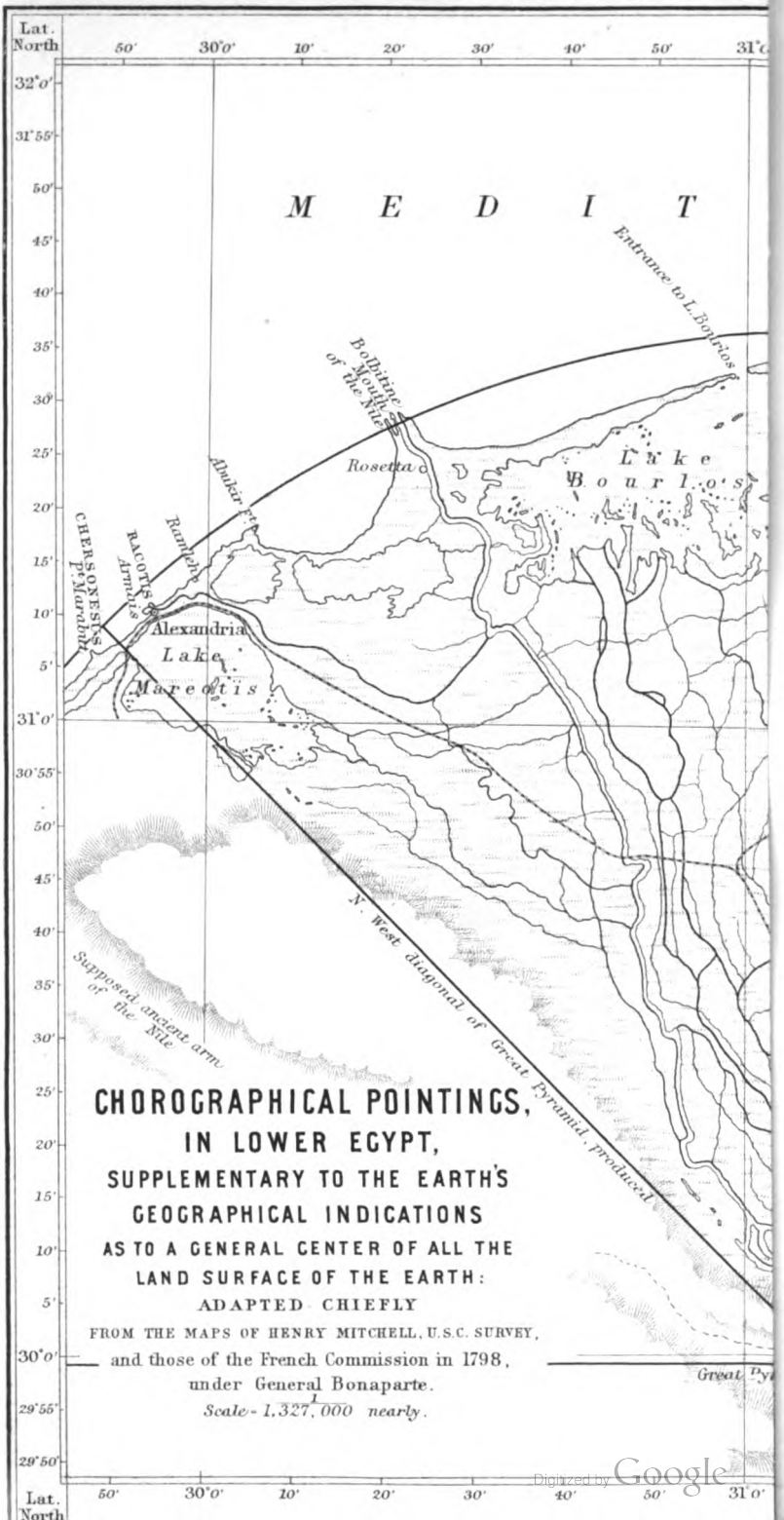
Lat. North
50'
30°0'
10'
20'
30'
40'
50'
31°0'
32°0'
31°55'
50'
45'
40'
35'
30'
25'
20'
15'
10'
5'
31°0'
30°55'
50'
45'
40'
35'
30'
25'
20'
15'
10'
5'
30°0'
29°55'
29°50'
MEDIT
Entrance to L. Boulros
Bolbitine Mouth of the Nile
Rosetta
Lake Boulos
Aboukir pt
Ramleh
CHERSONESUS pt Marabout
RACOTIS & Arnolis
Alexandria
Lake Mareotis
N. West diagonal of Great Pyramid, produced
Supposed ancient arm of the Nile
Great Py
CHOROGRAPHICAL POINTINGS,
IN LOWER EGYPT,
SUPPLEMENTARY TO THE EARTH'S
GEOGRAPHICAL INDICATIONS
AS TO A GENERAL CENTER OF ALL THE
LAND SURFACE OF THE EARTH:
ADAPTED CHIEFLY
FROM THE MAPS OF HENRY MITCHELL, U.S.C. SURVEY,
and those of the French Commission in 1798,
under General Bonaparte.
Scale - 1/1,327,000 nearly.
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Lat. North

The Portuguese are just as pronounced in reckoning only from Ferro; and

The North Americans are equally set, as shown by their last Nautical Almanac, on using Washington as their grand meridian.*

While Berlin, Altona, Pulkowa, and Vienna each have their special supporters.

12. CHOROGRAPHICAL ADDITION TO A GEOGRAPHICAL RESULT.

Now all this confusion and opposition in longitude, while the most admirable uniformity reigns in latitude, arises out of the belief that there is no one meridian pointed out by nature or proved by man, to be more appropriate for measuring longitudes from, than another.

But such a belief deserves now to be ranked among exploded errors; because

1*st.* Our Plate VII. shows three grand geographical approximations by nature to one chief meridian line.

2*d.* The same plate shows a semi-geographical feature telling the same story, or the one, both longest and most classic river of the whole earth, the Nile, flowing generally in a meridian direction through its whole course from its far off source to its well-known mouth, and close to the mean of the above three geographically indicated longitudes; and

3*d.* Plate VIII. shows a chorographical marking near that remarkable river's mouth, which, allying itself with topography leads up to a unique primæval monument of eminent mathematical shape, and in such substantial preservation as to its chief fiducial points, that it is well fitted for scientific reference still.

But as this chorographical finding was only very recently

---

* In an earlier part of that Almanac there are of longitude references to—

Paris,	23
Greenwich,	21
Washington,	
Berlin,	5
Altona,	4
Pulkowa,	3
Vienna,	2

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made by an American, Mr Henry Mitchell, M.A., Astronomer and chief Hydrographer to the United States Coast Survey (discovered too and printed by him when he was still unacquainted with our reasons 1 and 2), it had better be given in his own words.

13. MR HENRY MITCHELL'S RECENT DISCOVERY.

Mr Mitchell then was desired, in the years 1868–69, by his chief in office, Professor Pierce, to examine and report on the Suez Canal, and in the course of his investigations he paid much attention, as a hydrographical engineer, to the physical characteristics of the northern coast line of Egypt, a fertile subject of discussion among the learned from Herodotus down to the present time.

At pp. 6 and 7 accordingly, of an authorised copy of his report, printed in 1869, Mr Mitchell thus expresses himself:—

"Is it unreasonable to suppose that the Nile has changed its outlets whenever these have become so prolonged as to prevent great resistance to its floods, and that before the occupation of the country by dyke-builders the river was in some degree free to seek the shortest route to the sea, especially in periods of inundation? The conclusion is forced on my mind that, in ages past, the coast line, while slowly advancing upon the sea, must, in its general sweep, have oscillated about the arc of a circle, of which the centre was somewhere in the main artery of the great floods.

"My search for this central point led to a curious result. I took a string and pencil, and described upon Linant's chart successive circles, continually altering the position of my centre and the length of my radius, till I was satisfied that I had plotted the arc which best conformed to the general sweep of the coast from the tower of the Arabs to Peluse. Watching my arc, I had not perceived in what direction I had been shifting my centre, but now, lifting my finger to mark the point, I discovered beneath it the Pyramids of Gizeh! Subsequently I plotted the Great Pyramid upon the recent coast-chart of the Suez Canal

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Company, and found my previous result confirmed.* Situated upon the last rock that confines the floods of the Nile, this structure occupies a more important physical position than any other artificial object upon the face of the earth, since it is the centre from which radiated the waters of the river, and from which, from age to age, the coast may be supposed to have advanced in concentric arcs. With no predisposition to believe in the scientific purposes of the pyramid-builders, I nevertheless cannot help thinking that, if there ever existed a comprehensive and economical system of irrigation in Lower Egypt, this initial point must have been to the engineer one of primary importance."†

14. SIGNIFICANCE OF THE GREAT PYRAMID'S PHYSICAL POSITION.

Lower Egypt then, or the Delta of the Nile—and which all the world has long known to be more or less in the shape of a battle-axe blade according to the ancient Greeks, or a pear according to modern Arabs,—is thus shown by Mr Mitchell (and as may be seen in Plate v.), to be more exactly still of a sectorial figure, with the curved border of the sector turned northward to the Mediterranean Sea; while the centre of formation is situated towards the south at that

* "The latitude of the Great Pyramid (the more important element for this) was not long ago carefully redetermined by Professor Smyth, Royal Astronomer of Scotland. The longitude I took from Linant. I required my circles, as I drew them, to touch the outer rocks (contemporaneous formations) at Alexandria and Abou-Kir; to clear Cape Bourlos (which has, according to Beaumont, slightly retrograded under the action of the sea), and to fall in with the shore at Peluse, where the beach under the action of waves from the westward has advanced fifteen hundred feet since the days of Strabo, —*i.e.*, since the closing of the ancient Pelusic and Tanitic branches. Although my arc is over one hundred degrees, I do not pretend to distinguish between the Great Pyramid and its immediate neighbours of the same group."

† "Since writing the above, I have discovered the following passage in Girard (of the French expedition):—'The coast of Egypt, from Alexandria to Peluse, presents a great curve, turning its convexity to the north, upon which the point of Abou-Kir and the two outlets of the Nile are salients. Precisely in the middle of the distance which separates them (the outlets) we find Cape Bourlos, the most northern point of Egypt, situated upon the same meridian as the pyramids.' Except the allusion to Abou-Kir, this is correct.—H. M."

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narrow neck near modern Cairo and ancient Babylon of Egypt, where the waters which have come down for 2800 miles from the still further south in a single channel, suddenly begin to diverge into two principal, and many subsidiary, streams to form the characteristic Delta-land; and in fact have formed it age after age advancing in concentric arcs from that notable point, until the radial lines are now more than 100 miles in length.

Now these radial lines are by no means ideal only, but marked both by streams of flowing water, and by certain elongated sand-ridges on the land between, so that the whole of Lower Egypt is in effect a grand species of chorographical pointer to one particular spot; and when, seated upon that very spot,—mounted on the last or northernmost rock of the desert, we find the most gigantic, admirable, geometrical, and astronomical stone building of the ancient prehistoric world—we may well allow with Mr Mitchell that the site primevally chosen for that building, the centre of so many converging natural lines, is a more important *physical* site than any other yet occupied by human architecture over the whole face of the earth.*

15. THE GREAT PYRAMID AS A LONGITUDE MONUMENT.

Important that position of the Great Pyramid may be physically, a friend has already remarked, but has the Pyramid itself any direct reference to longitude?

That it *has* a singular claim that way is tolerably evident from this now historic circumstance, that "the meridian of the Great Pyramid" formed the central and constant longitude reference for the savants who accompanied Bonaparte

* Mr Mitchell goes still further, and recognises in the now proved position of the Great Pyramid a complete solution at last of a difficulty long felt in the Prophet Isaiah's sacred allusion, as it is believed, to the Great Pyramid, in his 19th chapter: viz., "an altar to the Lord in the *midst* of the land of Egypt and a pillar (a different name for the same object) at the *border* thereof"—physical impossibilities apparently to meet together, yet admirably illustrating the position at the base of the Sector shape of Lower Egypt,—viz. in or at the centre of the natural alluvial formation of the delta-land, and yet at the border, or almost on the outside, of the same land of Egypt.

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to Egypt in 1798, and is to be seen marked as such in the huge atlas of maps accompanying the great French work on Egypt, considered by them to be an immortal contribution to their national glory.

Those eminent savants must have also immediately perceived the adaptation of the whole figure of the Pyramid to form the best and most exact of triangulation signals over a vast extent of country; in fact the highest and best signal ever erected for the survey of any territory; and it is clear that they must also have perceived how the sectorial shape of Lower Egypt arranges itself symmetrically on either side of the *meridian* passing through the Great Pyramid; with such nicety too, that the northernmost point of the coast is both in the middle of the said curved coast-line, and in the same *longitude* as the Great Pyramid; while either side of the Delta-land conforms on the whole to the same building's diagonals produced. Not only so too, but we must give every credit to the French savants of a troublous period in the history of the world, for having seen and published that the Great Pyramid itself, planted on the top of a desert hill, with opportunity equally of facing any position, was at the time of its founding, oriented *astronomically* with astonishing precision, and was constructed with a vertical plane of passages sensibly in, and visibly marking, the meridian; while "it looks out," so to speak, through its only opening or communication with the external atmosphere, right away meridian-wise and northward, to where the northernmost point of Egypt resists the waves and shows to passing sailors the longitude of the Great Pyramid, though it is itself totally invisible from the sea.

So solid moreover has been the work of construction in that giant fabric the Great Pyramid, and so minutely accurate, that although it has come down to us from ages before all human history, yet the position of the entrance passage by reference to its admirable walls may be defined to within a tenth of an inch. While too this is actually more accurate than anything really required even in modern longitude work,—the building possesses unalterable temperature requirements still more happily adapted to longitude observa-

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tions. For these include, *par excellence* a knowledge of the time, together with the possession of, or power of referring to, the best possible standard clocks both for time-keeping and time-registration; and the latest conclusion of the most advanced astronomers in the principal European Observatories is, to place their central, or chief *motor* clock for the whole establishment in an interior chamber kept at a uniform temperature by the mere thickness of its walls and roof.

Now whereas the last announced case of improvement before the Astronomical Society of London described one gentleman as having, on the top of a hill, sunk a dry well 40 feet deep for his observatory clock,—and expecting, on that account in a great measure, to have the best clock in Europe,—the Great Pyramid has a chamber not only of costly material admirably finished, but surrounded on every side by nearly 200 feet in thickness of solid masonry, in a species of stone too supposed to be better calculated than any other to resist the passage of heat.

16. SUMMING UP OF EVIDENCES FOR A FIRST TERRESTRIAL MERIDIAN.

Thus then have we arrived by successive approximations, and such as were totally impossible to any of the nations of classic times, at a knowledge of one principal meridian for all the earth; defined and distinguished from every other by nature both geographically and chorographically; and then still further and more exactly marked topographically in ancient days, before human history began, with the greatest and most appropriate building of all the earth, whether to mark a surveying central station or define a meridian line, or to typify mathematics (whatever other purposes it may also serve), viz., the Great Pyramid. All this too in so perpetually central a country for all human times, both commercially and socially, that while the French Academicians of seventy years ago began their immortal volumes of the "Description de l'Egypte," with the words—

"*Situated between Asia and Africa, and communicating*

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easily with Europe, Egypt filled the centre of the Ancient World."

And while a later French authority, M. Ampère, wrote nearly thirty years ago—

"Egypt which awakens all the grand memories of the past, interests us yet in the present and the future: in the present by the agonies of her parturition; in the future through the destinies which Europe is preparing for her, so soon as Europe shall have taken possession of her, which cannot very long be retarded (now that the Isthmus of Suez has again become the high-road of nations, the link which unites the oriental to the occidental hemisphere) ——— Egypt a country formed to occupy eternally the world."

The last year has seen that Isthmus of Suez actually cut through; and astonished India, China, even California and Australia placed within comparatively easy and speedy reach both of Europe and the U. States of N. America.

But will modern nations ever use the Great Pyramid of Egypt as marking a *meridian* line for them all?

If they are ever to enjoy uniformity of longitude reckoning on their maps, they must come to use it—for it is their only hope.

Thus, if Britons are ever likely to surrender their Greenwich zero to any influences, it should surely be to those of justice and reciprocity with the hundred millions of their new fellow-subjects in India, just half-way between whose populous home and our Western Isle, the meridian of the Great Pyramid extends.

If France again ever consents to leave off reckoning from Paris, it will be in deference to her unexampled but most exemplary work of peace and progress at the Suez Canal, and to the actual commencement which her savants of the first Revolution did make under Napoleon Bonaparte, in heralding the way to nations and showing them how to use *the meridian of the Great Pyramid* as a geographical starting line.

America too will respect an antiquity of the early world so old as to excite no feeling of latter-day jealousy between her and its probable originators.

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17. A HYPOTHETICAL OBJECTION ANSWERED.

Certain worthy men still consider themselves compelled to object, that when the Great Pyramid was built, no Egyptians knew of the existence of America;—and that the centre of the land-surface of *their* world must consequently have fallen so far to the eastward, that the Great Pyramid could not have been built with any strict *intention* on their part of marking both a first meridian, and the centre of the then supposed anthropological land-surface of the whole world.

I shall not, however, presume on this occasion to occupy your time with any lengthy elucidations of the undying tale of wonder connected with the unique design and long hidden sources of origin, anything but Egyptian, of that primeval monument which stands in Egypt; for the story has been largely set forth in various published works; and justifies still more startling proofs of knowledge on the part of the unknown architect, infinitely beyond all that idolatrous man either knew, or could in any way find out for himself, at the time. Sufficient therefore just now, that the Great Pyramid *is* standing, according to all *our* knowledge of the earth in these days, exactly where it should stand for the longitude wants of *our* times; that we could not improve its position, were we to try; and that it is, year by year, attracting more notice to itself on that very account.

If any man then feels offended thereat, and if he is strong enough, let him take up the Great Pyramid and put it somewhere else. But until he has accomplished such a feat, there the rock-founded building stands, a solemn witness to us from the ages which are gone: and much, truly is it to be hoped that this Society, earnest for the progress of all science and striving for the increase of unanimity among nations, will not allow the public to lose sight of where the centre of the entire earth's land-surface really is, and how it was marked before human history began, and what else of note and appropriate character is also both waiting there at this very moment, and has been waiting there man's recognition during the last 4040 years.

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APPENDIX I.

Surface Temperature of the Earth in 30° *Lat. in either Hemisphere.*

Certain conclusions from Prof. Dove's isothermals of the earth led me several years since to announce 67°·2 Fahrenheit as *his* result for the mean temperatures of the surface of the world in 30° latitude in either hemisphere: the northern being 69°·1 and the southern 65°·4.

Subsequently referring to Principal Forbes' papers on terrestrial temperature, in the Transactions of the Royal Society of Edinburgh, vol. xxii. part i.; and seeing that he deduces by his physical theory founded on Dove's observations, that in a world wholly composed of land-surface the temperature at 30° in either hemisphere would be 80°·9 Fahr., and if wholly composed of a water-surface, would be 61°·9 Fahr.; I was led to multiply either of these quantities by the then believed respective amounts of land and sea surfaces in the world, or 515 and 1455; whence we have

$$\frac{80°{\cdot}9 \times 515 + 61°{\cdot}9 \times 1455}{515 + 1455} = 66°{\cdot}9$$

or 66°·9 is another result for the same physical datum of the world at large. Yet this represents in reality merely the observations collected by Dove in another shape: and we may state the whole result therefore more nearly and simply as 67°·0, with a margin of uncertainty depending on the character of the observations employed.

But these were manifestly deficient over large tracts of the earth, where there have not even yet been made any good meteorological observations. Under these circumstances therefore I was induced to hail as an admirable contribution to the enquiry a large atlas published last year by the London Meteorological Office on the temperature of the South Atlantic, and giving the results of recent observations, both British and Dutch,* on the surface temperature of

* These having been previously published by Dr Buys Ballot at Utrecht.

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that ocean for every month of the year, and in every 5-degree space; or much more extensively than in any case hitherto printed or known.

This fine monogram seemed useful to the enquiry because, although land observations are usually thought more accurate, they labour under greater chance of local variations, and require a correction to reduce them to the sea-level, which all sea observations are necessarily free from: the land moreover represents but a small part of the world's whole surface as compared with the sea, and has not the power of motion to equalize the temperature of its different portions as so eminently possessed by water.

Of all waters, too, the South Atlantic is a most admirable mixing basin of temperature for the surface of a large part of the earth; and if we combine the western side of the Indian ocean as well, given also in the Atlas quoted, we have warm currents which come down from northern latitudes of Asiatic seas, as well as the European, American and African currents on one side and Antarctic currents on the other side, of the actual South Atlantic.

There are indeed two grand disturbing causes to be carefully eliminated; *first*, the season of the year which may produce differences of so much as 10°; and *next*, the locality as to east and west side of the ocean, which may entail a difference nearly as great.

My method of proceeding therefore has been, to take out from the maps the observed temperature at every 5 degrees of longitude, and for the mean of the latitudes immediately above and below 30°, whenever observed; as shown in the following Table I. The blank spaces are due to no ships provided with thermometers passing that way, and render an *unexceptionable* mean very difficult to obtain.

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TABLE I.

Temperatures of South Atlantic Surface in 30° Lat. S., and at every 5° of Long. from the American, to the African, Coast.

Months.	W. 42°·5	W. 37°·5	W. 32°·5	W. 27°·5	W. 22°·5	W. 17°·5	W. 12°·5	W. 7°·5	W. 2°·5	E. 2°·5	E. 7°·5	E. 12°·5	Means.
	°	°	°	°	°	°	°	°	°	°	°	°	° Fah.
January....	75·0	75·0	74·1	75·1	73·9	...	...	...	...	...	66·8	67·1	72·4
February...	...	76·6	76·1	76·0	76·4	...	...	...	...	...	67·6	68·6	73·6
March.....	73·0	75·8	75·6	74·8	76·5	76·2	...	...	...	...	67·8	68·3	73·5
April.....	...	...	72·5	73·3	72·3	71·0	71·2	70·5	...	...	66·6	67·0	70·6
May	...	69·0	70·7	70·9	69·5	67·9	67·9	68·5	...	...	64·5	64·8	68·2
June.....	...	...	68·4	67·5	67·0	65·5	65·2	...	...	...	63·7	61·6	65·6
July	...	66·5	66·2	65·8	66·8	65·0	64·5	63·0	63·0	61·0	61·6	60·7	64·0
August.....	67·2	...	65·7	65·4	63·8	63·9	64·0	64·0	...	61·9	62·2	59·8	63·8
September..	...	63·5	63·8	63·5	64·5	63·7	63·8	62·0	...	...	60·8	60·8	62·7
October.....	65·8	...	64·4	64·4	64·6	63·8	63·8	...	...	...	61·2	60·8	63·6
November..	...	...	67·0	65·8	67·2	65·8	64·5	...	...	...	63 0	63·6	65·3
December..	...	...	69·0	71·7	71·5	68·2	...	...	...	...	65·2	66 0	68·6
GRAND MEAN,	...	...	....	...	...	...	...	...	...	...	...	...	67·7

TABLE V.

Surface Temperatures of Atlantic and Indian Oceans, on either side of S. Africa, on Parallel of Lat. 30° South.

Months.	E. side of Atlantic Ocean.		W. side of Indian Ocean.		Mean.
	7° 30′ E.	12° 30′ E.	32° 30′ E.	37° 30′ E.	
	°	°	°	°	° Fah.
January, . . .	66·8	67·2	76·2	75·9	71·5
February, . .	67·6	68·6	77·7	77·0	72·7
March, . . .	67·8	68·3	76·2	77·3	72·4
April, ...	66·7	67·0	73·9	73·8	70·4
May, ...	64·5	64·8	73·5	72·3	68·8
June, ...	63·7	61·6	69·9	70·9	66·5
July, ...	61·6	60·7	67·9	68·6	64·7
August, . . .	62·2	59·8	69·0	68·9	65·0
September, . .	60·8	60·8	69·6	68·8	65·0
October, . . .	61·2	60·8	69·2	69·4	65·2
November, . .	63·0	63·6	74·0	73·3	68·5
December, . .	65·2	66·0	75·0	73·6	70·0
Means, ...	64·3	64·1	72·7	72·5	...
Grand Mean, .	...	...	...	...	68·4

Whence we may perhaps safely conclude, that somewhere between 67°·7 and 68°·4 lies the true mean temperature of the earth's surface in the latitude parallel of 30°.

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APPENDIX II.

On the Map of Egypt in Plate VIII.

Plate VIII. is prepared mainly from Mr Henry Mitchell's map, and that again on the well-known and authoritative charts of Linant Bey and the Suez Canal Company.

In Plate XI., vol. iii., of my "Life and Work at the Great Pyramid," there are two miniature and rude maps of Egypt where the shape of the Delta is sensibly different from Mr Mitchell's; but these maps are of no authority on that question of Lower Egypt, for besides their smallness, they were taken from a single author who was intent only on proving a certain physical change chiefly in *Upper* Egypt.

I have since however examined the maps in the great French work, also those in Dr Lepsius' folio volumes, besides several independent modern maps of large size, and they are highly confirmatory of Mr Mitchell's coast outline; with the single engraver's mistake of having applied the name of Alexandria not to its real site at the eastern end of a long bay, but to a point of land at its western termination entitled in the various maps sometimes "Chersonesus" and sometimes "Marabut."

Within the coast line, Mr Mitchell's map, being *intended* for little more than a general sketch of the principal features, is deficient in the innumerable irrigating channels of Lower Egypt and the as numerous little islands in the shallow expanses of Lakes Menzaleh, Bourlos, and others; but these omissions are of no importance to our present question.

In my own M.S. map founded on Mr Mitchell's, I have coloured green the whole Delta down to the sea-coast. Some parts of this region, are indeed in fact neither green nor fertile, and show only yellow-ochry coloured hills of sand and limestone soil, as with the tract between Alexandria and Ramleh; but that tract, as I have myself witnessed, though it is never overflowed by the inundation, is in a manner *under*-flowed by the Nile all the year through, and water-wheels worked by oxen over wells some 30 feet deep bring up freely water in abundance: enabling an otherwise most absolutely

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sterile-looking country to keep in life occasional date-palms and small gardens—and form thereby a total contrast to the rocky desert on either side of the Delta.

The most interesting portions of the Delta's Mediterranean coast-line for our present enquiry, are the points where it is cut by the Great Pyramid's meridian line, and its N.E. and N.W. diagonal lines.

The meridian line cuts at the northernmost point, or the true Cape Bourlos; for the practice of some modern map-makers in giving the name, not to the northernmost point of the whole country, but to one side of the entrance into Lake Bourlos several miles westward thereof, is not borne out by the older maps. Outside that present mouth, the French charts note "Ruins of a castle and village under the water," and there are other proofs of Cape Bourlos itself having suffered degradation within the historic period: so that even if there had been once a monument there to connect it with the Great Pyramid, it would probably have been submerged before this. The locality is however peculiarly distinguished in the old French charts by the large amount of date-trees and villages "with some ruins"—compared with the bareness of the sand-dunes on either side, and it might be worth while to have the region well explored for its extreme antiquities.

Still more probably would it repay to explore where the Great Pyramid's N.E. and N.W. diagonals cut the coast: for while they in a manner define the limits of the Delta on either side all the way along, they go on to cut the coast, the former near the site of the ancient Pelusium, and the latter to the west of Alexandria.

Pelusium itself is indeed only a Greek city, and as even the Kadesh Barnea of the Bible was of no very great antiquity, —but then it had been built, according to W. Osburn, on the site of *Chatash*, a memorable Egyptian city under the 18th dynasty, and was distinguished in the hieroglyphic pictures of that time by an eminent mound in its neighbourhood, of apparently higher antiquity still,—or possibly coeval with the foundation of the Great Pyramid.

Similarly Alexandria, near the N.W. diagonal line of the

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Great Pyramid produced, is not old enough to be of importance from its Greek foundation; but to the west of it have been discovered, according to W. Osburn, columns of temples marked with the name of a king of the 18th dynasty, and some still older obelisks. The region therefore eminently requires exploration anew, with men's wits sharpened to recognise—not the decorated architecture, and granite statues of the New Empire, which they are usually looking for in general Egyptian researches,—but the more modest and exact geometrical workings of the Old Empire. The distance is such as to be wholly out of eye-shot from even the summit of the Great Pyramid,—and any marking of the coast in connection therewith would raise important speculations as to the Pyramid-builders' means of observing, and their intentions in their work.

Notice of an Improvement on the Mode of Collecting Bilge-Water in Ships within the Action of the Bilge-Pumps. By Heriot Currie, F.R.S.S.A., Chief Engineer N.L.S. "Pharos."*

The improvement I am about to describe is so simple, that were it not for its importance and the generality of the grievance requiring to be remedied, I would almost shrink from laying it before the members of this Honourable Society.

It is a well-known fact to all employed at sea, and to others who by force of circumstances are obliged to take this mode of conveyance, that the bilge-water of all vessels is a great nuisance, for these reasons—viz., the bad odour it emits, the noise it creates, and the unsteady motion it gives a vessel when gathered in any considerable quantity; this accumulation usually occurs when a vessel is heavily laden, when labouring in a rough sea, or when overtaken in a storm; how it gets into the vessel is sometimes difficult to discover; as on examining a vessel in harbour or dry dock it may appear so tight that one would think no water could get in or gather in the bilges, and so cause trouble and danger; yet

* Read before the Society 9th May 1870, and awarded the Macdougal Brisbane Prize, value Six Sovereigns.

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from all experience it is found that most seaworthy ships make large quantities of bilge-water.

From my own experience, now extending over a period of nearly twenty-three years, and, I may also add, that of all connected with steam iron ships, either paddle or screw, that they also make bilge-water less or more, partly from leakage, through straining, and also from the leakage of cocks, bad joints, &c.

To make the matter clear, allow me to explain—1*st*, In all sea-going vessels it is the carpenter's duty, and in most coasting vessels the boatswain in addition to the carpenter, to sound or measure the water in the fore and aft holds, morning and evening. This is done by letting down through a tube fitted for the purpose a rod covered with chalk and fastened to a cord, so that when drawn up it shows the depth of water in the bilges; but as the vessel rolls, the water rushes from side to side, so that if the carpenter or boatswain are inexperienced, or not very careful to watch the opportunity to let down the sounding-rod when the vessel steadies on even keel, it may only show 1 inch when rolling, and 12 inches or more when upright; this uncertainty of measurement I purpose to remedy.

2*d*, The present insufficient mode of preventing the water from rushing across the ship is by having what is known as washboards, which are generally pieces of wood or iron fitted and rivetted, or driven in tight between the frames at about 1 inch below the floors, and 1½ inch up from the shell or ship's bottom, but always in such a position as to allow the water to pass freely either way; thereby the water is only partially hindered from moving in a body, but is not prevented from leaving the centre of the vessel, where the bilge pumps are usually placed, and can alone reach the water to pump it out.

3*d*, That the annual loss and damage to cargo by bilge-water is considerable, I have, by careful inquiry, learned from captains, engineers, and seamen of long experience, also by those long engaged in shipping companies' offices; and merchants can also tell of losses they have sustained by goods being damaged at sea with bilge-water washing up

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through the floors and sides. To prevent this damage in steam-vessels, valuable goods are generally stowed on the upper or midship deck, and cargo not easily damaged in the lower hold, yet not close to the bottom or sides, but kept off the floors and sides by pieces of loose wood; while in sea-going vessels carrying valuable cargoes of tea or tobacco, &c., the cargo is kept upwards of 2 feet from the bottom or sides by first a layer of gravel (if it can be got), over it loose pieces of wood called dunnage—the distance being lessened in thickness as the cargo rises towards the deck. My proposal will save this loss of stowage room and greatly lessen the cost of dunnage.

4th, In all iron vessels there must be a great weight of bilge-water, but more particularly in large vessels, such as the s.s. "Scotland" (now lying at Granton Pier, built by Mr John Key of Kirkcaldy), which measures 305 feet in length and 38 feet beam, with a depth of bilge below the floors of 2 feet by 20 inches wide at the kelson. Now, suppose there are six inches' depth of water in each of these spaces, what a great weight of water must be at the ship's side, when she lies over; whereas, if that weight of water was kept in the centre, it would greatly help to bring her up to even keel, and possibly answer the purpose of water ballast now used in iron ships, as illustrated by accompanying drawing, being a sectional view of a vessel lying over, to show the action of the proposed bilge-valves with a weight of water passing under the one and prevented by the other from going beyond the action of the bilge-pumps. A, shows valve open. B, opposite valve shut.

5th, It is so well known to all connected with iron vessels, that I may affirm it without fear of contradiction, that nearly every time steamers are put on the slip or in the graving dock, to get their bottoms cleaned and painted, when carefully examined inside, where not covered with cement, a great number of rivets will have to be taken out and replaced by new ones, their heads being worn clean off by the action of small coals, ashes, clinkers, &c., that may have fallen through the floors into the bilges, and by the water rolling from side to side, thereby acting as files

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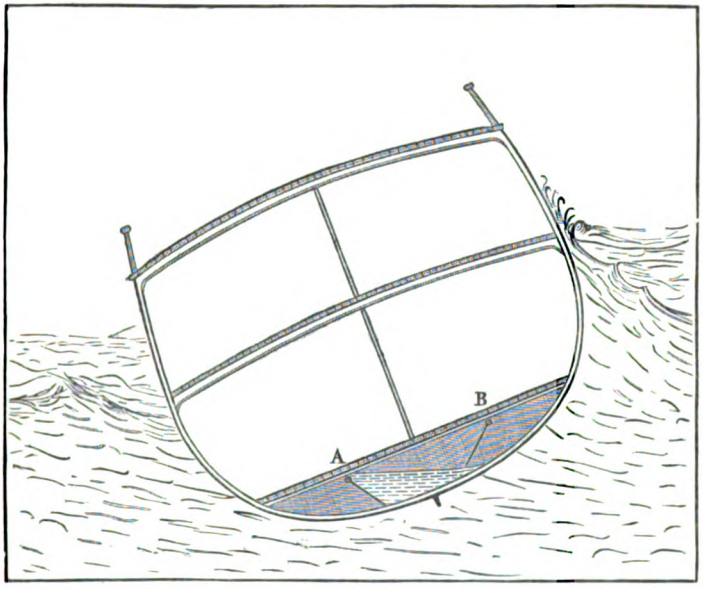
on the projecting rivet heads, grinding them quite off, and sometimes leaving the bodies of the rivets so loose that they are in danger of dropping out of the hole, and leaving a dangerous leak. This may happen under the cargo, boilers, coal bunkers, or other places that cannot be readily got at in time to save the vessel, so that it is quite possible this may have been the cause of the mysterious leak that resulted



in the loss of the steamship "Gambia" on her passage from London to Aberdeen. I could also name another vessel that had few rivet heads left on one part of the hull, even while she was carrying passengers and cargo. Besides the rivet heads being worn off, the landing or joints of the plates get worn to so near the rivet holes that new plates have also to be fitted and rivetted on to protect these weak and worn landings, thereby lessening the hold of the original firm rivetted joints, and so weakening the vessel, besides costing considerable outlay and waste of time.

What I now propose as a cure for all these grievances is no mere theory, but a tried remedy now in use to a limited extent in the N.L.S. "Pharos," and may also be by others

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(to whom I have described the plan) who were troubled, as I have been, with the bilge-pumps not being able to catch the water when the ship rolled.

During last winter I fitted a piece of $\frac{1}{16}$ sheet iron to a $\frac{8}{8}$ tube between the frames, hinged at an angle of 45°, so as to fall by its own weight on the points of two bolts screwed into the frames, and going into the ends of the tube, and acting like a valve or sluice on hinges, opening by the water as the ship rolls. The valves are placed 4 feet on each side of the keel, and the water opening and passing under the one valve shuts the other: thus the water is gradually collected between the two valves—which prevent it from ranging across the ship's bottom, and if not immediately pumped out, it acts as water ballast, by being confined in mid-ship.

The plan has answered beyond the expectation of myself and many others who have examined and approved of it as a practical and useful improvement.

The plan is thus proved to possess the following advantages:—

1*st*, Safety to the vessel, by affording a sure means of knowing the exact quantity of bilge-water in the ship.

2*d*, To collect the water in such a position that the bilge-pumps can have command of it.

3*d*, Protection to the cargo from damage by bilge-water.

4*th*, By confining the bilge-water to the centre of the vessel, it thereby acts as water ballast, and assists the vessel to right herself.

5*th*, To save the vessel from the internal tear and wear caused by the hard substances carried to and fro across the ship's bottom by the bilge-water, and thereby grinding the rivet heads off and cutting the plate-landings.

The extreme simplicity of the plan, its easy adaptation to either old or new vessels, the very small cost, combined with its durability and little chance of getting out of order, will, I hope, recommend the proposal to the favourable consideration of this Society and the notice of the mercantile marine service, in whose safety we are all interested.

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Self-Registering Rain Gauge. By JAMES S. WATSON, Madhapoor.*

In India, where so much depends on the rain-fall in bringing forward the crops, and supplying tanks and reservoirs, the Government are very particular in ascertaining the quantity, and having it reported as accurately as possible.

All Europeans and natives in charge of districts are provided with the ordinary tube and rod to measure the fall after each shower, but as the natives cannot be depended on either to empty the tube regularly, or note the quantity accurately, the heads of the department have been anxious to get a self-registering gauge.

The Crossley self-registering gauge is said to be the best in Great Britain; but it has a long train of wheels, and is rather complicated for India, as the natives have no idea of reading off the 10th's, 100th's, and 1000th's, as in a gas meter.

The late Colonel Dyer of the Irrigation Department spent some years in bringing out his Rain-Gauge, but it did not work satisfactorily, having too many bearings, one or other of which was always getting out of order, and it was owing to so many of his instruments being sent to the Government workshops at Madhapoor for adjustment, that caused Mr Watson to turn his attention to the matter. After considerable labour and many experiments, he succeeded in bringing out the gauge now before you. It has been well tested; some of them have been working for several years without getting out of order. All the principal stations in the Punjaub have been supplied with them; and Mr Watson finding it impossible to meet the demand, brought, or rather intended to bring, one with him when he came to England last year, in order to have them made in this country; but, unfortunately, the box in which it was was sent by a vessel round the Cape, and did not arrive till he had started on his return. He, however, left such a description of it with me, that when I saw it, I could easily understand the working of it. The silver medal of the Agra Exhibition of 1867 was awarded Mr Watson for the invention.

* Read before the Society 9th May 1870, and awarded the Society's Honorary Silver Medal.

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A great desideratum in making an instrument of this sort is to have as few working points, so as to have as little friction, as possible. In the present case the motion power is very small, and there are only two bearings or moving points. The main one being that on which the buckets swing; the other, that on which the main indicating wheel revolves—and it is not possible to make a self-registering instrument with less. The spindles on which these move are silver-plated, to prevent corrosion.

Owing to the great number of sparrows and other birds in India, a sparrow rail on the top has been found necessary, and most effectual in preventing their droppings getting into the works, stopping up the discharge tube, and deranging everything. In India the end of the discharge tube is covered with perforated zinc to prevent reptiles and insects building their nests inside the instrument.

The receiver measures 10×10 inches, showing a surface of 100 square inches. The water for this receiver runs into two buckets placed on an upright hinge, and are each made to tilt on receiving 5 square inches, being the 20th part of an inch of the surface of the receiver. The double tilt, of course, gives the 10th.

The capacity of the buckets is tested by means of a tube made to contain 5 inches of water, or the 20th part of the surface of the receiver. The fall of its run into the buckets should cause them to tilt. If not correct, there are adjusting screws to each, so that they can be very accurately set.

The motion of the buckets, by means of pins attached to the side of each, gives the action to the wheel by the scape movement working into the teeth, on the front of the face wheel. This wheel is divided into fifty equal parts, and has fifty teeth, which are each lifted by a right and left tilt of the buckets, so that 100 tilts, or fifty lifts, complete the revolution, and show that 5 inches of rain have fallen.

The outside surface of the wheel is also divided into fifty 10ths, and is read through the small opening in the right hand side of the instrument, and the moment 5 inches are indicated on the dial (the pointer of which is moved by a

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spur on one of the teeth of the wheel), they are also shown on the large wheel through the opening.

The index dial is made to read up to 100. Supposing the pointer was at 25, and the 3·9 presented at the opening or eye-hole, the quantity indicated would be 28 9-10ths.

The utility of the arrangement will be obvious in setting up the gauge in an out-of-the-way district. After being properly adjusted the hand on the index dial is set at 100, and the wheel at the side door to lead of 0·0. Thus set, at the beginning of the rainy season in India by the European in charge of the district (who may not have an opportunity of visiting it again till the rains are over), he will have the quantity accurately registered; or, if he has a sufficiently intelligent native in charge, he could register the fall daily.

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On the Distillation of Gas from Coal in Short-Time Charges as compared with Long-Time Charges. By STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry.*

The scientific principles which regulate the distillation of gas from coal have not hitherto demanded that attention which the importance of this branch of technical chemistry undoubtedly deserves. In Scotland, the supply of cannel or parrot coal, at a comparatively cheap rate, from fields blindly supposed to be inexhaustible, and in England the intense desire to consider the coke as of equal if not greater importance to the gas, have probably heretofore led scientific as well as practical men to regard this branch of industry as in a sufficiently forward condition, and as quite able to take care of itself. Now-a-days, however, more attention must be paid to the subject. Gas-works are multiplying and extending. The consumption of coal is yearly increasing, and some of our best seams are giving alarming evidence of exhaustion at no very distant day. It behoves us, therefore, to discuss the scientific principles which regulate the distillation of gas from coal, so as best to know whether we are proceeding in the right direction in our every-day work, and whether we are adopting the most economical method of distillation.

For some years I have directed my attention to this subject, and have not only studied the chemistry or scientific part, but, by means of thoroughly equipped apparatus, have been enabled to make a large number of experiments which have led to important practical results.

The chemical formula for pure wood is $C_6H_{10}O_5$, being 6 atoms of carbon, 10 of hydrogen, and 5 of oxygen; and as each atom of carbon weighs 12, each atom of hydrogen 1, and each atom of oxygen 16, it follows that the actual proportions by weight, in which the elements are chemically united in the wood, are—carbon $6 \times 12 = 72$, hydrogen 10, and oxygen $5 \times 16 = 80$, making altogether 162. During

* Read before the Society, and illustrated by diagrams, on 11th July 1870 Awarded the Hepburn Prize, value seven sovereigns.

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the natural decay of those ligneous and other vegetable matters, which have ultimately led to the formation of our coal-fields, the hydrogen and oxygen have been in greater part, and the carbon in lesser proportion, removed in the form of carbonic acid, CO_2, light carburetted hydrogen, CH_4, hydrogen, H, water, H_2O, &c., leaving the coal with a comparatively greater percentage of carbon than what was present in the original ligneous or vegetable matter. The composition of pure wood and cannel coal, in 100 parts, clearly shows this:—

	Ligneous Matter. Pure Wood.	Average Sample of Cannel Coal.
Carbon, ...	44·44	75
Hydrogen, ...	6·17	7
Oxygen, ...	49·39	9
Nitrogen, ash, &c., . . .	...	9
Total, . . .	100·00	100

During the distillation of the coal for gas in ordinary retorts there are produced, by the destruction of the coal, a number of different gases and vapours, including heavy carburetted hydrogen, C_2H_4, light carburetted hydrogen, CH_4, carbonic oxide, CO, hydrogen, H, and nitrogen N, besides other substances which are arrested either in the condensers or in the purifiers. The coal-gas, therefore, as ordinarily used, is a heterogeneous mixture of many different gases, of which the carburetted hydrogens are the luminous members, and the remaining gases are either faintly luminous or are non-combustible. The light-giving carburetted hydrogens are not confined to the two gases which have the chemical formulæ of C_2H_4 and CH_4, but are also present as C_3H_6 and C_4H_8, when they possess even greater luminosity in burning. It is manifest, therefore, that the larger the proportion of the carburetted hydrogens, the greater the photogenic or light-giving power of the coal-gas, whilst, when the other gases, such as carbonic oxide, hydrogen, and nitrogen, are present in increased amount, the luminosity of the coal-gas must decrease in a corresponding degree.

During the earlier part of the distillation of gas from a charge of coal in the ordinary retorts, the light-giving car-

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buretted hydrogens preponderate, whilst in the later stage of the process the less luminous gases are present in the greatest volume. It is manifest, therefore, that the first portions of gas evolved from a charge of coal will possess a much higher photogenic power than the last portions. The specific gravity or density of the earlier gas is also greater than that of the later gas, owing to the difference in the respective weights of the various gases which form the heterogeneous mixture known as coal gas. Thus, taking air as 1000, the heavy carburetted hydrogen, C_2H_4, has the specific gravity of 978; light carburetted hydrogen, CH_4, 557; carbonic oxide, CO, 967; and hydrogen, H, 069. So that the hydrogen is eight times lighter than the light carburetted hydrogen, and fourteen times lighter than the heavy carburetted hydrogen.

Besides the quality of the coal which is employed in charging the retorts, there are various circumstances which influence the photogenic value of the gas; such as the temperature of the furnace, and the length of time which the charge is kept in the retorts. A low heat leads to the obtainment of a small volume of gas of comparatively high quality, and reduces the proportion of non-luminous gases to a minimum; but such a method of procedure is far from economical, owing to the loss of luminous matter in the distillation of oil, and of vapours which condense either in the ordinary condensers or in the gas-holders and pipes. A high heat, on the other hand, increases the volume of gas at the expense of the luminosity, for it not only adds largely to the proportion of hydrogen and other non-luminous gases, but it tends to decarbonize or withdraw carbon from the more highly luminous gases. Thus heavy carburetted hydrogen, C_2H_4, even when formed from the coal, is reduced to light carburetted hydrogen, CH_4, when allowed to impinge upon an over-heated retort, there being at the same time a deposit of the missing atom of carbon in the interior of the retort. Indeed, the undue heating of the gas may cause the separation of the whole of the carbon from C_2H_4 to CH_4, and to H itself, when the carbon is deposited in the retort, and the hydrogen, now expanded to double the volume

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of the original carburetted hydrogen, passes through the meter and is recorded as gas. It will thus be observed that a low temperature in the distillation of gas is wasteful, owing to the production of oil and condensable vapours, and a high temperature is wasteful, from the decarbonisation of the luminous gases. The skill of the gas engineer lies in determining the proper heat which will at the same time prevent, on the one hand, the distillation of oil and non-permanent gas, and, on the other hand, the destruction of the more useful gas.

Even when the proper heat has been commanded there are various suggestive points to be considered; such as the duration of the time of the distillation of each charge, and the most economical way of using coals in mixture or otherwise.

The time during which each charge should be heated in the retort must depend much on the quality of the coal itself, but there is reason to believe that the period might be materially shortened with great advantage to the photogenic or light-giving power of the gas, though at the same time to a loss in the total quantity of the gas. The decrease in volume, however, is mainly in those gases which are faintly or not at all luminous, but which in burning evolve the highest heat. Many experiments were made by me with cannel or parrot coals for the purpose of arriving at correct and trustworthy data as to the difference in the quantity and quality of the gas evolved from such coals, when distilled in long or full-time charges as compared with short-time charges. In both sets of trials, the retorts and furnaces were kept as nearly as possible at the same heat, and the only difference in the mode of working was, that, whilst in the long or full-time charges the gas was practically worked out of the coal in the time and manner followed in ordinary gas-work experience, in the short-time charges the gas was eliminated from the coal for a period of time equal to about three-fourths of that which was occupied in the long or full-time charges. In other words, where a charge would be heated for four hours in the long or full-time mode of working, a similar charge was heated only for three hours in the short-

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time trials, when the operation of distillation was stopped, and the coke was withdrawn.

The coals experimented upon were the Haywood cannel coal, the Bank gas coal (both upper and lower seams), the Lochgelly parrot coal, and the Raith parrot coal. The detailed results of the practical trials are given in the following tables, where the yield of gas in the long-time charges may be contrasted with that given in the short-time charges:—

Haywood Cannel Coal.

	Long-Time Charges.	Short-Time Charges.
Yield of gas from one ton of the coal, ...	11,153 cub. ft.	9333 cub. ft.
Specific gravity of the gas (air = 1000), . . .	572	591
Total weight of the gas from one ton of the coal, . .	489 lbs.	423 lbs.
Condensation by bromine = heavy hydrocarbons, . .	15 per cent.	16 per cent.
Durability of the gas—1 cubic foot burned at a 4-inch single jet, ...	73 min.	76 min.
Ditto, 5-inch ditto, . . .	58 „	61 „
Illuminating power of the gas —5 cubic feet burned during the hour from a No. 5 fishtail or union burner—in standard sperm candles, . . .	30·97 candles	34·87 candles
Total illuminating power of the gas obtained from one ton of the coal in pounds of sperm,	1178 lbs.	1144 lbs.

These results show that in distilling the Haywood cannel coal in short-time charges, as contrasted with long-time charges, the yield of gas decreased from 11,153 to 9333 cubic feet, being 1820 cubic feet, or 1-6th less gas; that the candle power increased from 30·97 to 34·87, being a difference of 3·90 candles, or 1-8th more; and that the total illuminating power of the gas from 1 ton of the coal decreased from 1178 to 1144 lbs., being 34 lbs. deficiency, or 1-35th of the whole light.

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Bank Gas Coal—Upper Seam.

	Long-Time Charges.	Short-Time Charges.
Yield of gas from one ton of the coal,	10,080 cub. ft.	8516 cub. ft.
Specific gravity of the gas (air = 1000),	527	543
Total weight of the gas from one ton of the coal,	407½ lbs.	355½ lbs.
Condensation by bromine = heavy hydrocarbons,	14 per cent.	15 per cent.
Durability of the gas—1 cubic foot burned at a 4-inch single jet,	74 min.	77½ min.
Ditto, 5-inch ditto,	59 „	62 „
Illuminating power of the gas —5 cubic feet burned during the hour from a No. 5 fishtail or union burner— in standard sperm candles,	27·67 candles.	31·45 candles.
Total illuminating power of the gas obtained from one ton of the coal in pounds of sperm,	956 lbs.	918 lbs.

In this case the Bank gas coal gave 1564 cubic feet less gas by the short-time charges, which is equal to 2-11ths of the whole yield by the long-time charges; but the candle power was raised 3·78, or 1-8th more, and the total illuminating power of the gas from 1 ton of the coal exhibited a decrease of 38 lbs., or 1-25th of the whole.

Bank Gas Coal—Mixed upper and Lower Seams..

	Long-Time Charges.	Short-Time Charges.
Yield of gas from one ton of the coal,	10,126 cub. ft.	8468 cub. ft.
Specific gravity of the gas (air = 1000),	524	542
Total weight of the gas from one ton of the coal,	407 lbs.	352 lbs.
Condensation by bromine = heavy hydrocarbons,	13·75 per cent.	14·8 per cent.
Durability of the gas—1 cubic ft. burned at a 4-in. single jet,	71 min.	77 min.
Ditto, 5-inch ditto,	57 „	61½ „
Illuminating power of the gas —5 cubic feet burned during the hour from a No. 5 fishtail or union burner—in standard sperm candles,	27·07 candles.	31·28 candles.
Total illuminating power of the gas obtained from one ton of the coal in pounds of sperm,	940 lbs.	908 lbs.

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The mixed seams of the Bank gas coal thus yielded by the short-time method of working 1658 cubic feet less gas, or 1-6th of the total quantity; whilst the photogenic power of the gas rose 4·21 candles, or 1-7th more, and the light from 1 ton of coal decreased 32 lbs., or 1-30th of the total quantity.

Lochgelly Parrot Coal.

	Long-Time Charges.	Short-Time Charges.
Yield of gas from one ton of the coal, ...	10,040 cub. ft.	8460 cub. ft.
Specific gravity of the gas (air = 1000), . . .	515	532
Total weight of the gas from one ton of the coal, . .	396½ lbs.	845 lbs.
Condensation by bromine = heavy hydrocarbons, . .	11·5 per cent.	13 per cent.
Durability of the gas—1 cubic ft. burned at a 4-in. single jet	65 min.	70 min.
Ditto, 5-inch ditto, . . .	52 „	56 „
Illuminating power of the gas —5 cubic feet burned during the hour from a No. 5 fish-tail or union burner—in standard sperm candles, .	26·24 candles.	29·82 candles.
Total illuminating power of the gas obtained from one ton of the coal in pounds of sperm,	903 lbs.	865 lbs.

The Lochgelly parrot coal, therefore, gave in the short-time charges 1580 cubic feet, or 1-6th less gas; the illuminating power of the gas rose 3·58 candles, or 1-7th more; and the total light was 38 lbs. less, or 1-24th of the whole amount.

Raith Parrot Coal.

	Long-Time Charges.	Short-Time Charges.
Yield of gas from one ton of the coal, ...	9630 cub. ft.	8180 cub. ft.
Specific gravity of the gas (air = 1000), . . .	511	526
Total weight of the gas from one ton of the coal, . .	377½ lbs.	330 lbs.
Condensation by bromine = heavy hydrocarbons, . .	11 per cent.	12·5 per cent.
Durability of the gas—1 cubic foot burned at a 4-inch single jet, ...	64 min.	69 min.
Ditto, 5-inch ditto, . . .	51 „	55 „

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Average Results of Experiments—continued.

	Long-Time Charges.	Short-Time Charges.
Illuminating power of the gas —5 cubic feet burned during the hour from a No. 5 fish-tail or union burner — in standard sperm candles, . .	25·61 candles.	29·26 candles.
Total illuminating power of the gas obtained from one ton of the coal in pounds of sperm,	845 lbs.	822 lbs.

This coal, in the short-time charges, yielded 1450 cubic feet, or 1-7th less gas; the photogenic power increased 3·65 candles, or 1-7th more; and the total gas from one ton of the coal was equal to 23 lbs., or 1-37th less than in the trial with full-time charges.

The foregoing results as given in the five different sets of trials may be averaged as follows:—

Average Results of Experiments on Different Coal.

	Long-Time Charges.	Short-Time Charges.
Yield of gas from one ton of the coal, ...	10,205 cub. ft	8591 cub. ft.
Specific gravity of the gas (air = 1000), . . .	529 8	546·8
Total weight of the gas from one ton of the coal, . .	415·5 lbs.	361·1 lbs.
Condensation by bromine = heavy hydrocarbons, . .	13.05 per cent.	14·26 per cent.
Durability of the gas—1 cubic foot burned at a 4-inch single jet, ...	69·4 min.	73·9 min.
Ditto, 5-inch ditto, . . .	55·4	59·1 „
Illuminating power of the gas —5 cubic feet burned during the hour from a No. 5 fish-tail or union burner — in standard sperm candles, .	27·51 candles.	31·33 candles.
Total illuminating power of the gas obtained from one ton of the coal in pounds of sperm,	964·4 lbs.	931·4 lbs.

From this latter table it will be observed that the average of the five trials shows a decrease of 1614 cubic feet, or fully 1-6th of the full quantity; whilst the luminosity has increased 3·82 candles, or fully 1-7th more; and the total

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illuminating power of the gas from 1 ton of the coal exhibits a deficiency of 33 lbs., or 1-30th of the whole light.

A summary of all these results is given in the following table:—

Summary of Results of Experiments in the Distillation of Gas from Cannel Coals in Long-Time Charges compared with Short-Time Charges.

Name of Coal.	Mode of Distillation.	Yield of Gas from One Ton of the Coal.	Total Weight of Gas from One Ton of the Coal.	Illuminating Power of Five Cubic Feet of the Gas in Standard Sperm Candles.	Illuminating Power of the Total Gas from One Ton of Coal in Pounds of Sperm.
		Cubic Ft.	lbs.	Candles.	lbs.
Haywood Cannel Coal	Long-Time Charges	11,153	489	30·97	1178
	Short-Time Charges	9,333	423	34·87	1144
	Difference . .	1,820	66	3·90	34
Bank Gas Coal, Upper Seam .	Long-Time Charges	10,080	407½	27·67	956
	Short-Time Charges	8,516	355½	31·45	918
	Difference . .	1,564	52	3·78	38
Bank Gas Coal, Mixed Upper and Lower Seams . . .	Long-Time Charges	10,126	407	27·07	940
	Short-Time Charges	8,468	352	31·28	908
	Difference . .	1,658	55	4·21	32
Lochgelly Parrot Coal	Long-Time Charges	10,040	396½	26·24	903
	Short-Time Charges	8,460	345	29·82	865
	Difference . .	1,580	51½	3·58	38
Raith Parrot Coal	Long-Time Charges	9,630	377½	25·61	845
	Short-Time Charges	8,180	330	29·26	822
	Difference . .	1,450	47½	3·65	23
Average Results of Five Experiments . . .	Long-Time Charges	10,205	415·5	27·51	964·4
	Short-Time Charges	8,591	361·1	31·33	931·4
	Difference . .	1,614	54·4	3·82	33·0
		Being fully 1-6th less Volume of Gas.	Being fully 2-15ths less Weight of Gas.	Being fully 1-7th more Illuminating or Photogenic Power.	Being 1-30th less Total Light from Gas yielded by One Ton of Coal.

The advantages and disadvantages of working on short-time charges, as compared with long-time charges, may be

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summed up as follows:—The advantages are, the increase of the candle power of the gas, and the exclusion of a considerable amount of gases, which are mainly dilutants of ordinary gas, and which are objectionable, owing to the large share they have in the production of heat in our apartments. The disadvantages are, the loss in the volume of the gas, even though it be of a faintly luminous nature, and the deficiency in the total light yielded by the gas from 1 ton of the coal, even though that amounts only to 1-30th of the whole available light—coupled also with the extra expense of working the retorts. The more the matter is looked at, however, the advantages appear all the more clear and decided. The increase in the candle power will admit of less expensive coals being employed in the distillation of better gas, for the difference in the mode of working insures a rise of nearly 4 candles in the quality of the gas. The comparatively useless nature of the gases which are excluded may be learned from the fact that, whilst 1-6th of the total volume of the gas is held back, there is only 1-30th less light from the ton of coal. Moreover, the coke of the short-time charges, when withdrawn from the retorts, does not evolve much luminous gas, and it appears well-nigh exhausted of all its light-giving power. We may safely, therefore, affirm that the distillation of gas from coal by short-time charges is to be commended, because of the better quality and increased luminosity of the gas, and the comparative exclusion of gases which are more heating than luminous in their nature. These results point to the general use of gas with the greatest amount of pleasure and benefit to the consumer, and probably also from the possibility of employing cheaper qualities of coals, to the pecuniary gain of the gas manufacturer.

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On Rainfall and Evaporation in its Relation to Water Supply. By ALEXANDER LESLIE, C.E., F.R.S.S.A., Assoc. Inst. C.E.*

The subject of water supply is one of such great importance to the inhabitants of all towns and villages, that a few remarks on it scarcely require to be prefaced by an apology.

It is true that there are many who, if their pipes run full, and their cisterns are well supplied, are satisfied that all that is needed is there, and care not to inquire whence this blessing comes, or what is the primary source from which it is derived. Others, however, interest themselves not only in the derivation of the supply, but take pleasure in investigating the many curious facts connected with it which are laid before us, and for which we are indebted to the careful series of observations, made both by private individuals, and those whose duties lead them, so to speak, personally more in contact with the element, and also to the series of observations which are carried out under the auspices of the Meteorological Society. The most important fact which must be impressed on those who are to examine the subject, is, that all water, through whatever medium it is ultimately derived, whether impounded floods are utilized, as in the case of Manchester, Liverpool, and many other places, or whether springs furnish the supply, as is partly the case in our own city, or whether the water is derived from deep wells, either spontaneously, as in the case of the artesian wells of Grenelle, or are forced from their low level by pumping engines, as is so common now in many places not naturally favoured with sources on a high enough level to be supplied by gravitation, and, with the exception, however, of the supply of those unfortunates, who, as I am informed, in several parts of Australia, derive their much prized drop of water from large establishments erected for the purpose

* Read before the Society on 23d January 1871, and awarded the Society's Silver Medal, value seven sovereigns.

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of distilling the salt water of the ocean; I say the fact to be observed is, that all water comes originally from the clouds, which one might say was sufficiently obvious, without further discussion; but although, perhaps, no one will actually argue the reverse, yet I don't think it is so generally accepted as universally true, as it certainly is. It is interesting to observe how this fact is taken notice of by King Solomon, who seems to have been one of the very first to turn his attention to the science of meteorology, as we find it beautifully and concisely stated in the following verse,—"All the rivers run into the sea, yet the sea is not full—unto the place from whence the rivers come, thither they return again."

Much has been written and much said about the available proportion of rain which can be counted on as capable of being utilized for the purposes of water supply, and we are indebted to Mr Ramsay, late Vice-President of this Society, and Manager of the Water Company, for the paper contributed by him on the subject some years ago; but as the area treated of by him was limited, and the number of experiments from which he deduced his results were few, it must not be surprising if the results set forth in this paper should differ very materially from those to be expected after studying the paper submitted by him. Another very important consideration, and one of special interest to those to whose care is entrusted the construction of large reservoirs, is the maximum flow per minute off each acre of drainage ground, as, for instance, during the erection of an embankment, sufficient sectional area must be given to the culvert or tunnel, through which the flood water of the stream to be impounded is to pass—to permit of its free egress, and avoid any damming up of impounded water behind, which, when it overtopped the bank, then but half constructed and unfinished, would be certain to burst out, and rushing down the natural channel of the river, would carry devastation and destruction before it. This is no hypothetical case, but one of which instances have occurred, though fortunately not very often.

During the construction of the Glencorse reservoir, from

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which part of the Edinburgh water supply is derived, an unusually great flood caused the water to rise nearly up to the level of the unfinished bank, and it was only by the use of every means in their power, by spreading tarpaulins and other coverings over the exposed face of the puddle wall, that those in charge of the work could attempt to avert the threatened danger; but fortunately the flood abated before the embankment was really overtopped. At Threipmuir, from a similar cause, though there is a two-feet pipe through the bank, there was danger and actual loss. Another more serious result of insufficient means of escape for flood water is recorded by Mr F. Bateman in his account of the Manchester floods which occurred during the progress of the construction of reservoirs, on the River Etherow, which he was making for the supply of that town. He tells how the rain fell in quantities hitherto unheard of, and how, to the horror of all concerned, he found the discharge pipes, of which there were two laid, each 4 feet in diameter, quite inadequate to the wants of the occasion; and finally the water, rising gradually inside the embankment, as before described, found its way over the top of the dam, which, by the wasting effect of the overflowing water, was soon overthrown, and the impounded water, bursting out in an irresistible flood, rushed down the valley, effecting loss of property, and the destruction of whatever opposed its downward career. Fortunately, on this occasion, the inhabitants of the valley below, and through which the flood would pass, had been warned of the approaching enemy, so no lives were sacrificed, but only property suffered to the amount of several thousand pounds. The amount of impounded water thus permitted to escape was fourteen million cubic feet, and although this was equal to the contents of the Bilbury Reservoir at Holmfirth, which burst in 1852, and which was the cause of so many lives being sacrificed, still the natural configuration of the valley through which this Manchester flood passed, being flat and broad, allowed of the water passing by in a manner comparatively innocuous, when compared to the dire results which accompanied the bursting of the Bilbury Reservoir. This latter embankment had 80 feet of

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water heaped up behind it, and the whole gave way simultaneously; whereas the Manchester one had only 27 feet, and wasted more slowly, being much more substantially and carefully built. Although I mentioned hydraulic engineers as being principally interested in the maximum floods per acre, the designers of culverts and bridges for railways and roads have as much need to see that they provide sufficient passage for flood water, as although the results to the public may not be so serious, still the failure of the works is a result which is certain to happen if sufficient attention be not paid to their design. In India especially, we have accounts of the frequent failures of bridges and viaducts from this cause; but to this subject I shall have occasion to refer before the end of this paper.

To return to the original subject, namely, the loss by evaporation and absorption, and the remaining quantity of water which can be counted upon as available for water supply, I propose to give in detail the result of experiments made at different places to ascertain the extent of this loss, and shall begin with the experiments of Mr Thom, of Rothesay, M. Inst. C.E., the object of which was to determine the quantity of water which should be given annually to the mills situated on a stream, the water of which it was proposed to divert and utilise for the supply of Paisley.

The district which was proposed to be employed for this purpose was that of Gleniffer and Harelaw, lying to the south of Paisley, having respectively a drainage area of 624 and 166 acres. The experiments extended over a period of three years, and by them the portion of the whole rainfall actually available, was found to be 70,354,769 cubic feet per annum, which is equivalent to 31·06 inches, out of 46·13 inches, falling over an area of 27,189,063 superficial feet, one-fourth of which quantity, equally distributed, was given to the mill-owners.

Thus the quantity lost by absorption and evaporation was found to be equal to 15 inches of the annual rainfall. This result corresponds exactly with the observations of Mr Hawksley, M. Inst. C.E., who has devoted much time

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and attention to this subject, as mentioned in Vol. XVII. of the Transactions of that Institution.

At the Rivington works of the Liverpool Corporation, the water is collected from a mountain range ascending to an elevation of 1600 feet above the level of the sea. The drainage area comprises sixteen square miles, from which flow three principal rivers, and many minor streams. The geological formation is that of the silicious rocks underlying the coal measures. The average fall of rain is upwards of 50 inches annually, and the quantity collected is about 36 inches, leaving for evaporation and absorption 14 inches. In another volume of this work we find the following, as stated by Mr Robert Manning, M. Inst. C.E.:—Twenty or thirty years ago the evaporation was taken at one-sixth, one-third, two-thirds, of the mean annual rain, according to circumstances. At the present day the balance of opinion seems to be that the amount of evaporation is not proportional to the rainfall, but that it is either constant or within narrow limits when there is any identity or similarity in the physical features of the districts compared, that it varied under different circumstances in the kingdom from 9 to 19 inches, and that the estimated amount for any particular case must be left to the experience and judgment of the engineer. From a table supplied by this authority, we have laid before us a statement of the rainfall and available supply, and the loss by evaporation and absorption, obtained from a series of observations which extended from the year 1851 to 1864 inclusive, and which result in the fact that the rainfall varied from 28·8 in 1855 to 47·71 in 1852, the average of the fourteen years being 38·42; and the available amount in the same years was 14·57 inches and 35·37, and the average of the fourteen years 27·71; while the loss on these same years was 14·23 and 12·34, giving us an average of 13·71, which is not much different from the other two authorities already quoted.

The loss varies from 11·79 to 15·16 inches, and the supply from 14·57 to 35·37.

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TABLE OF RAINFALL OF WOODBURN DISTRICT NEAR CARRICKFERGUS, IRELAND.

Year.	Rain.			Loss.	Supply.
	Winter.	Summer.	Total.		
1851	15·76	19·98	35·74	13·94	21·80
1852	29·70	18·01	47·71	12·34	35·37
1853	20·13	19·03	39·16	12·01	27·15
1854	16·58	17·98	34·56	14·23	20·33
1855	10·91	17·89	28·80	14·23	14·57
1856	15·96	18·99	34·95	15·01	19·94
1857	22·03	12·51	34·54	11·79	22·75
1858	20·42	20·64	41·06	15·16	25·90
1859	21·68	13·33	35·01	11·86	23·15
1860	21·86	22·48	44·34	14·40	29·94
1861	17·58	21·87	39·45	13·68	25·77
1862	24·15	21·29	45·44	14·15	31·29
1863	19·12	23·72	42·84	14·38	28·46
1864	17·47	16·78	34·25	14·81	19·44
Average	19·53	18·89	38·42	13·71	24·71

Another authority, however, Mr Bailly Denton, takes a different view of the question, as recorded in another page of that journal, saying that he believes that there is a prevalent opinion that the amount of evaporation varies from 13 to 17 inches, giving a mean of 15 inches per annum. This assumption, he considers, was contradicted by the fact that in August 1859 the evaporation exceeded the rainfall by 3 inches, while in the same month of 1860 the rainfall exceeded the evaporation by the same amount, thus making a difference of 6 inches, showing the incorrectness of considering evaporation as a constant quantity, and the fallacy of quoting means and averages in water questions. I, however, am at a loss to follow the reasoning, as in the absence of the knowledge of what were the respective quantities of rain and evaporation, which he does not supply, we are at liberty to assume the evaporation to be constant, and the rainfall to be the changeable quantity.

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I propose next to refer to a series of experiments made for the purpose of ascertaining the annual available flow of the Reivoch Burn and its tributaries, a stream in Renfrewshire, which was intended to be adopted as the source of supply for the town of Paisley, in addition to the supply formerly alluded to, and the works for introducing which were successfully completed and formally opened in the spring of 1870.

Four gauge weirs were erected on the tributaries, the united waters of which form the burn, across which the main embankment of the store reservoir was placed, and the water flowing over them was measured every day. There were also two rain-gauges placed in the neighbourhood, of which a careful register was kept. One of these was placed at Springside, at a level of 540 ordnance, and the other at Muirhead, at a level of 490 ordnance. Of 1050 acres of drainage area, the rainfall of 700 is represented by the Springside gauge, and the Muirhead gauge represents the rainfall of the remaining 350 acres. The following table shows the amount of rainfall registered in these gauges from December 1865 to December 1866 :—

Date.	Springside.	Muirhead.
1865 December, . .	9·89	7·75
1866 January, . . .	10·64	8·30
,, February, . . .	6·13	4·75
,, March, . . .	2·41	2·15
,, April, . . .	4·05	3·40
,, May, . . .	2·12	1·50
,, June, . . .	2·75	2·10
,, July, . . .	4·05	2·82
,, August, . . .	5·30	4·80
,, September, . .	7·15	6·00
,, October, . . .	4·55	3·30
,, November, . .	5·35	3·92
Total, . .	64·39 ins.	50·79 ins.

It is a curious thing that there should be such a very wide difference between the amount of rainfall registered in these two gauges, which are situated within half a mile of each other, and with a difference of elevation of only 50 feet; but the results found recorded in other years represent the same proportion of increase in favour of the higher one.

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Discharge over the Four Gauges.

1865 December,	16,658,006
1866 January,	38,706,722
,, February,	27,797,639
,, March,	7,866,099
,, April,	4,497,024
,, May,	3,372,013
,, June,	1,089,197
,, July,	2,210,871
,, August,	17,984,693
,, September,	25,441,959
,, October,	12,183,975
,, November,	21,860,127
	179,658,325

The quantity of rain falling on 700 acres, with rainfall of 64·39 inches = ... 163,614,990

And quantity of rain falling on 350 acres, with rainfall of 50·79 inches = . . 64,548,695

Total rainfall = 228,143,685

And subtracting total measured by weir = 179,658,325

Leaves for loss by evaporation, . . 48,484,360

which amounts to 12·72 inches of the rainfall, leaving 51·67 inches available for the high ground, and 38·07 for the low ground.

This quantity of 12·72 agrees very closely with the results before mentioned, certainly close enough, I consider, firstly, to prevent the theory of a percentage of the rainfall appear to deserve credit, and I think also to justify one in putting down certain limits for the loss suffered in this country, which in the four examples before us vary between 12·72 and 15·16.

The next source to which I would direct your attention is the district of the Caddon and Luggate in Selkirkshire, where a series of observations were made, commencing September 1869, and continuing for a period of twelve months.

These rivers were at one time suggested as proper sources to select for the supply of Galashiels with water, and in

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order to enable the promoters to speak with confidence as to the annual flow, two gauge weirs were erected on the Luggate and one on the Caddon, near to where good sites for embankments were found, and a rain-gauge was placed in each of the districts at a height above the ordnance datum of 1100 feet. In order to do full justice to this investigation, I propose to adopt the method usually suggested by Mr Hawksley under similar circumstances, namely, having got the rainfall in inches at any particular level, to add 2½ per cent., or $\frac{1}{40}$th of an inch, to every inch of rainfall for every 100 feet of elevation in the drainage area, and as is necessary in this case to subtract the same quantity from every zone of 100 feet below the level of the rain-gauge.

Taking, however, first of all, the rainfall as we find it registered, as was the case in the other calculations, we find that there was a rainfall of 35·05 inches over an area of 4528 acres, or 197,257,600 square feet, which is equivalent to a total quantity of 575,992,192 cubic feet. The result of the monthly gaugings over the weir, however, gave a quantity of 280,450,409 as the amount flowing off, leaving for evaporation and absorption a quantity of 295,541,783, which is equivalent to an amount of 18 inches annually. As this quantity greatly exceeds what we find within a short distance of this place, I cannot but think that some floods may have been allowed to pass unnoticed.

Passing to the Luggate, which is only a few miles north of this, we find the highest of the two gauges on it, which is placed near Nethershiels, gives us the annual flow off 4165 acres, which is equal to 181,410,300 superficial feet, 309,938,664 cubic feet; and the rainfall, which is equal to 33·44 inches, would yield 504,320,634 cubic feet, leaving for evaporation and absorption the quantity of 194,381,970 cubic feet, which is equal to a loss of 12½ inches, leaving available 21 inches.

The other gauge has a total drainage of 4528 acres, equal to 255,562,300 superficial feet, and the amount flowing off was measured at 411,794,200; and the rainfall, being taken at the same as above, 33·44, represents a total fall of 710,463,194

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cubic feet, which leaves for loss by evaporation and absorption a quantity of 298,668,994, being equivalent to 14·5 inches.

Taking it now with the alteration on the rainfall to suit the different zones of elevation, we find for the Caddon the corrected rainfall gives over an area of 4528 acres, or 197,257,600 square feet, a total quantity of 626,289,749 cubic feet. The result of the monthly gaugings over the weir, however, gives, as before mentioned, a quantity of 280,450,409 as the amount flowing off, leaving for evaporation and absorption 345,839,340, which is equivalent to an amount of 20½ inches annually.

Taking now the Luggate at Nethershiels, we find in the highest of the gauges on it an annual flow off 4165 acres, which is equal to 181,410,300 superficial feet, of 309,938,664 cubic feet; and the corrected rainfall yields 592,206,690 cubic feet, leaving for evaporation and absorption the quantity of 282,286,026 cubic feet, which is equivalent to a loss of 18½ inches.

In the other gauge, with a total drainage of 4528 acres, equal to 255,562,300 superficial feet, the amount flowing off was measured 411,794,200; and the corrected rainfall represents a total fall of 795,859,949 cubic feet, which leaves for loss by evaporation and absorption a quantity of 384,065,749, being equivalent to 18 inches. Of course this principle of augmentation is open to objection, and to that I shall have occasion to refer in a short time.

I had intended to refer to the district of Dunfermline, which I consider one particularly suitable for making observations such as these, as the drainage area, whose water we have to measure, is of a comparatively regular configuration without any extraordinarily high ground, which might greatly affect the amount of rainfall, but unfortunately there have been no proper gaugings kept of the amount of water used and wasted. I now propose to consider for a few moments the districts of the Glencorse valley, being the area treated of in Mr Ramsay's paper before alluded to.

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Taking, therefore, the waste water which flowed over the weir, we have—

		Inches.	Cub. ft. per minute.
1869 January	1 to 6	2	829
	6 to 13	1	294
	13 to 20	2	829
	20 to 27	2	829
	27 to Feb. 3	3½	1920
February	3 to 10	3½	1920
	10 to 17	3	1530
	17 to 24	2¾	1344
	24 to March 3	2¼	990
March	3 to 10	2	829
	10 to 17	1¼	408
	17 to 24	1	294
	24 to 31	½	105
			13)12,121
			932

Having as the average of thirteen measurements 932 feet per minute over a period of ninety days, which represents a total waste of 120,787,200 cubic feet. Throughout the year there was sent to the town 188 feet per minute = 99,864,000
And 220 feet for compensation to the mills = 115,632,000
Giving a total of 336,283,200
being a draught from the reservoir of 215,496,000 cubic feet.

In Glencorse reservoir, 1st January, was .	58,824,588
31st December, .	29,824,588
Loss, . .	29,000,000
In Logan Lea reservoir, above and running into Glencorse, 1st January, . . .	19,588,731
31st December, . .	22,901
Loss, . .	19,565,830
Total taken from reservoirs, ...	48,565,830

Subtracting which from total amount run off, ... 336,283,200
48,565,830
Leaves . 287,717,370 as total yield of district during year 1869.

Dividing this quantity by 160,920,640, being the number of square feet in 3694 acres, gives as available 21·384 inches,

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which, being deducted from total rainfall of 32·50, gives 11·1 inches for evaporation and absorption.

Taking, however, this district, and treating it with the increased rainfall before alluded to, we have the following, the results of which are given without the details :—

Glencorse, 32·5 inches over an area, allowing for increased rainfall in high lands.

Total rainfall, . 461,344,824
Total discharge, . 287,717,370

160,920,640)173,627,454(108 × 12 = 13 in. evap.
160,920,640

127,068,1400

This result does not seem at all too great to make us doubt the correctness of the principle.

Then looking at last year, 1870, which was remarkable for drought almost everywhere in this country, we have a rainfall of 27·7 inches registered in this district, and the total measured as sent to the town, and also for compensation, amounts to 158,022,387 cubic feet; and as those reservoirs were never full during the whole year, there is no chance of error arising from incorrectly registered waste. Deducting this quantity from the total of 371,726,678, which is equal to 27 inches, over the drainage area we have left 213,704,291 cubic feet, which represents a loss by absorption and evaporation of 15½ inches, being the greatest of which we have any record in the Glencorse district. Recent investigation, however, has led me to suspect that the quantity of waste mentioned as having occurred in the year 1869 has been overstated, so that the amount of loss, which is set down at 11·1 inches and 13 inches, is probably considerably under the actual quantity.

I may also mention the result of observations made on the Bavelaw district, of which the delivery from the springs is separated from the ordinary surface water, which being impure and mossy, and unfit for domestic use, is impounded and sent down as compensation to the millowners on Bavelaw Burn and Water of Leith.

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Taking the whole yield of the district, both spring water, compensation water, and the water wasted over the weir, we have

	Rainfall.	Available quantity.	Loss.
1860	38·20	25·67	12·53
1861	40·30	27·84	12·46
1862	42·20	27 54	12·63
1863	36 70	25·18	11·52
1864	38·30	35·60	2·70
1865	34·90	25·14	9·76
1866	39·50	28·90	10·60
1867	35·80	27·60	8·20
1868	41·40	31·00	10·40

In the case of the year 1864 the loss of 2·7 is evidently incorrect, owing probably to incorrect returns, as is also the case in some other returns which I had before me, but which I do not think it necessary to quote.

I am indebted to Mr Sang, of Kirkcaldy, for some information which I have received from him relative to the rainfall and flow in the Lothrie Burn, lately appropriated for the water supply of Kirkcaldy and other neighbouring places. The drainage area on which the observations were made was 1836 acres, the elevation of which varied from 795 to 1713 feet ordnance, and the rain-gauge was placed near the lower end of the watershed at an elevation of 650 feet. The observations lasted from June 1866 to June 1867, and the following is the result:—

1866.	Average flow cub. ft. per min.	Total rain per month, inches.
June, . .	123	2·09
July, . .	219	3·52
August, . .	257	5·07
September, .	293	4·33
October, . .	341	1·95
November, .	497	2·67
December, .	570	3·25
January, . .	1017	5·61
February, . .	704	2·22
March, . .	432	2·87
April, . .	437	3·92
May, . .	424	4·12
		41·62

The flow was observed once every day.

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From this it will be seen that the total available rainfall, as represented by the water flowing through the gauge, was 172,231,680 cubic feet, and subtracting this amount from the quantity of 277,515,175 cubic feet due to a rain-fall of 41·62 inches over an area of 79,976,160 square feet, leaves for loss by evaporation and absorption a quantity of 105,283,495 cubic feet, which is equal to 16 inches per annum. Allowing now for the increased amount of rain in the high grounds, we have to augment the 41·62 inches by a quantity = 3½ inches, which is 2½ per cent. at the average elevation, which is 1000 feet; and then we have, by performing the same operation as mentioned above, the result = 19 inches of loss per annum.

To consider for one moment the propriety or the reverse of trusting to this principle of augmentation of the rain-fall for increased elevation of the district, take a look at the following table, which is the result of observations taken in the lake country of Cumberland and Westmoreland:—

Place.	Elevation.	Average depth of rain-fall in inches.	No. of years of experiments.
Scafellpike, . .	3166	81·27	7
Lingmill, . .	1778	95·23	4
Great Gabel, . .	2925	90 32	7
Sprinkling Tarn, .	1900	135·91	7
Styehead Pass, .	1443	122·88	6
Brunt Rigg, . .	924	98·65	5
Wastdale, . .	166	112·16	7
Seatollar Common, .	1388	113·67	7
The Style or Sprinkling Fell, . .	948	172·45	3
Borrowdale. . .	242	149·85	7
Keswick, . . .	258	60·64	9
Bowness, . .	246	79·00	3
Loweswater, . .	336	68·14	9
Buttermere, . .	283	85·46	9
Gatesgarth, . .	326	116·70	9
Grassmere, . .	180	106·78	4
Langdale Head, .	250	124 01	8

This of itself would be sufficient to prove the fallacy of

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this system taken in every case, though, of course, it may happen that the rule may hold good in particular cases; but, of course, when we reached great elevations the rule obviously cannot be expected to hold, as the district being above the lower range of the clouds, cannot possibly have any great amount of moisture deposited on it. Take, however, the series of observations in the neighbourhood of Galashiels which bear out this principle. The elevation of the rain-gauge is 450, and registered the following quantities:—

September,	5·21
October,	1·72
November,	2·45
December,	4·50
January,	2·70
February,	2·94
March,	1·26
April,	0 49
May,	3·45
June,	3·25
July,	1.26
August,	1.67
Total registered,	30·90

And the rainfall before alluded to, as registered in the Caddon gauge, which is placed at the level of 1100 ordnance, registering 35·05; and the difference of level by the formula would give 4·9 of increase, which, being added to 30·9, would give 35·8, leaving as difference between the actual quantity registered and the amount found by the formula three-fourths of an inch, which is within 2 per cent. of the actual quantity. As yet there has been no systematic attempt to obtain data for verifying this or any similar theory; but I hope that before long a series of experiments shall have been set afoot, so as to enable one with greater certainty to speak of the effect of increased elevation on the amount of rainfall. The operation would be simple enough, and not at all costly, to obtain permission from the proprietor of any suitable tract of country, and engage the services of some trustworthy person to make the observations monthly.

The next part of the subject, and one which I previously noticed as being of much importance, was the maximum

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floods to be provided against flowing off each acre of drainage area. Taking first in order the gaugings at Rowbank, we have, on 20th day of September 1866, the quantity of 3344 cubic feet per minute, which, the drainage area being 1050 acres, represents a quantity of 3·2 cubic feet per minute per acre. Turning to the Luggate, which has furnished us with other observations, we find that, on the 28th day of February, the flow at Nethershiels per minute was 15,682 cubic feet, which represents a quantity of 3·7 cubic feet per acre. As to the other gauge on the Luggate, and that on the Caddon before referred to, unfortunately there is no flood of any extent registered, which shows that the measurement for the day must either have been made before the flood began or not till after it had begun to subside.

Then, taking the waste weir at Glencorse, we have what cannot be considered a fair result, as the surface of the reservoir serves to impound a large quantity which should pass off at once in order to give the proper result; and occasionally, when the water is seen to be rising higher than is considered safe, the outlet tunnel is opened, and a quantity of water is permitted to escape, which is not measured.

Maximum Floods in Glencorse District.

	Glencorse. Flow per min. cub. ft.	Ft. per min. per acre.	Loganlea. Flow per min. cub. ft.	Ft. per min. per acre.
Nov. 25, 1861,	9300	2·62	...	...
March 1, 1862,	8616	2·43	...	...
Feb. 2, 1864,	7950	2·24	...	...
Oct. 29, 1864,	5460	1·54	2350	1·60
Jan. 30, 1867,	6600	1·58	1600	1·08
Feb. 23, 1867,	6600	1·58	2750	1·85
	Threipmuir.		Harlaw.	
March 14, 1864,	18,061	5·	24,510	6·2
Oct. 23, 1864,	26,764	7·4	37,511	9·9
Oct. 23, 1868,	9,482	2·6	18,082	4·6
	Crosswood.		Harperrig.	
Nov. 3, 1865,	4420	1·2	Nov. 30, 1864, 2731	·6
Dec. 10, 1865,	6760	3·2	Dec. 5, 1864, 3060	·7
Jan. 8, 1870,	7420	3·5	Jan. 10, 1865, 3107	·8
March 1, 1870,	8740	4·1	Jan. 30, 1867, 3107	·8
			Feb. 5, 1868, 3908	·9
			Oct. 23, 1868, 5616	1·4

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These, though considerable floods, are nothing to the floods mentioned as having been observed by Mr Bateman in the north of England. In the twenty-second volume of the Transactions of the Inst. C.E., during the discussion which followed the reading of a paper on the Upper Thames, by Mr Clutterbuck, Mr Bateman remarked that all the information that could be obtained as to the amount of floods, the manner in which they rose and the causes to which they were attributed, was valuable in an agricultural and engineering point of view.

During the years 1833, 1856, and 1857, he had the means of ascertaining, with great accuracy, the quantity of water flowing off the ground in a given time by the river Medlock at Manchester. That river was a short stream, running through the city of Manchester, and draining only about 12,000 acres, principally of clay land. The maximum quantity of water passing off in those years was equal to a depth of 4 inches, 5 inches, and 6 inches respectively every twenty-four hours; that was, the volume of the floods, when at their maximum was such, that those would have been the depths of water flowing from the ground had the floods continued at the same height for twenty-four hours consecutively. At the Manchester Water Works, during the flood of February 1852, to which I have alluded at the commencement of the paper, the water which came down from a district of 15,400 acres was measured either in reservoirs or through discharge pipes and gauges. The flow, when at the highest, was from 3600 and 4000 cubic feet per second, or 25 feet per second for each 100 acres, or 15 cubic feet per acre per minute, being at the rate of between 6 and 7 inches in twenty-four hours. In 1856 the quantity of flood water flowing into the Woodhead Reservoir of the Manchester Water Works, from an area of 7000 acres, was equal to 2100 cubic feet per second for seven hours forty minutes, or a depth of $2\frac{1}{4}$ inches, being at the rate of 7 inches in twenty-four hours. This quantity was equal to 18 cubic feet per acre per minute. In 1849, during the early progress of the work, a flood occurred at Woodhead, which, at its maximum, amounted to 50 cubic feet per second

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for every 100 acres, or 30 feet per acre per minute. During the flood of May 1862, at the Woodhead Reservoir, for the same district of 7000 acres, for a period of two hours and a half, the flow was equal to 22½ cubic feet per minute per acre. For seven hours it amounted to $14\frac{8}{10}$ cubic feet per minute per acre, and for thirteen hours to 9⅓ cubic feet per minute.

At the Glasgow Water Works, in October 1854, the flood from Loch Lubnaig, Loch Voil, and Loch Doine (the water surface of the lochs being about $\frac{1}{34}$th of the total drainage area of 44,600 acres) was equal to 328,000 cubic feet per minute, or a depth of 3 inches flowing off in twenty-four hours and 7½ cubic feet per acre per minute. On the same day, the volume of the flood flowing out of Loch Vennachar, from a drainage area of 45,800 acres, but where the surface of the lochs of $\frac{1}{11}$th of the whole, the flood only amounted to 150,000 cubic feet per minute, not one-half of that which flowed from Loch Lubnaig, from about the same area, and the same rainfall. This shows the regulating effect of large reservoirs, or sheets of water, to which I have already alluded.

In the River Clyde, at Carstairs, in the winter of 1856–57, from a drainage area of 190,000 acres, the flow of water was equal to 20,000 cubic feet per second or 6 feet per acre per minute.

From a table of the measured maximum quantities of water in the extensive valley of the Shannon, measured at Killaloe, we have the following:—The drainage area amounts to a total acreage of 2,560,000, and the quantity of water in flood was 1,600,000 cubic feet per minute. The discharge from various large rivers into the basin of the Shannon, from actual measurement in flood, varied from 0·76 to 1·54 cubic feet per acre per minute, the latter being a maximum. This result contrasts very strikingly with the quantities that we have recorded as flowing from mountain districts in England and Scotland, where they amounted to 6, 7½, 9⅓, 15, 18, and, in one case, 30 cubic feet per acre per minute.

This being the case, we see what great differences exist between the two localities referred to; so it is evidently

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improper to suppose that one river can be taken as a guide for calculations with reference to another, unless the natural configuration of the district were somewhat similar.

In conclusion, I have thus attempted to lay before you the results of observations and calculations from which we may be enabled to deduce rules which may assist us in investigating questions relating to the available amount of water to be counted on as flowing from a certain area, the rainfall of which is known; and also I have tried to point out how great a flow per minute may be expected to pass off the drainage area being dealt with, which, as we have seen, varies greatly with the nature of the district; and if any person, whether member of this Society or not, has the means in his power and at his disposal to add to the stock of information which we already have on this important subject, I think you will all agree with me in thinking that the trouble taken by him in doing so will not be labour spent in vain.

On Water Meters, as in use by Water Companies, and Design for simplifying and cheapening their construction. By JOHN REID, F.R.S.S.A., Engineer and Manager of the Edinburgh and Leith Gas Company.*

Mr Reid at some length explained the functions of the water meter, and some of the difficulties attending their construction, due to the non-elastic character of water and the conditions under which it is supplied and drawn off for consumption. As compared with the ordinary gas meter, which he explained by a diagram exhibiting its principle of action, the water meter is necessarily a more complex instrument.

Water meters may be divided into two distinct classes: *Low-Pressure* and *High-Pressure* Meters. The first are represented as a class by those which discharge definite quantities of water by successive and intermittent actions out of measuring chambers of known capacity, into cisterns situated underneath for its reception, the mere weight of the water

* Read before the Society, and illustrated by diagrams and working models, on 27th February 1871. Awarded a Keith Prize, value ten sovereigns.

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being generally employed as the moving agency. Of this class of meter I exhibit a diagram and working model of what I consider one of the best instruments of the kind, being the invention of Mr James Stirling, C.E., Edinburgh.

The high-pressure meters require to deliver the water at higher levels than themselves, and are impelled in some cases by the mere *velocity* of the current of water passing through them, but in most instances by the *pressure*, independently of velocity; the pressure upon the *inlet* being that due to the height of the fountain head, and the pressure on the *outlet* to the height at which the discharge takes place. As examples of the high-pressure class of meters, a series of diagrams were exhibited, showing the internal structure and mode of action of some of the best known and most extensively employed meters, including those known as "Kennedy's," "Frost's," "Worthington's," and "Siemen's," the first three being modifications of a cylinder and piston action, and each exhibiting different arrangements for effecting the reversing actions of the pistons, which in a water meter presents difficulties that do not exist with an elastic fluid like steam in reversing the motion of the piston of a steam engine. Siemen's meter does not deal directly with the *bulk* of the water like the others, and may be more correctly termed an *indicator* or inferential instrument, the quantity being determined by the velocity imparted to a nicely balanced vertical spindle, carrying at its lower extremity a hollow revolving chamber, with jets of water issuing at a tangent from orifices on its circumference, and by the reaction causing it to revolve at greater or less speed, according to the velocity and intensity of the jets; the ratio of speed to volume being ascertained, a registering index outside converts the discharge of water into gallons.

In most of the instruments referred to there are a number of working parts. In some of them a good deal of complication, rendering it impossible to produce them except at very considerable cost for material and workmanship; eight guineas may be taken as about the average price of a meter with a service pipe one inch in bore.

Some years ago I studied the subject, with the view, if

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possible, of devising something simpler and cheaper as a water meter than those already known, and as the result of my labours now exhibit, for the first time, a diagram and working model of a meter prepared and fitted up by myself, of which the following is a general description :—

Instead of employing the ordinary form of piston, traversing a cylinder alternately from end to end, and hampered by the friction of packing, stuffing boxes, and multiplicity of movements, I have adopted a light and easily fitting metallic piston of a rectangular form, revolving on one of its edges around the axis of a short cylinder, while its opposite edge sweeps the inner circumference of the cylinder, and moving so freely that a few inches of *head* pressure would be sufficient for its impulse. The small amount of leakage that might pass the edges of the piston is not to be measured by the greater or lesser head *pressure of water*, but is obviously proportioned to the resisting *weight* of the piston only, and therefore the amount of such leakage per revolution or per action has to be added to the volume discharged by each stroke, and taken account of by the registering index. The chief novelty in this instrument consists in the compound kind of movement performed by the piston within the measuring cavity of the meter. Although the piston always moves round in the same direction, it cannot be strictly termed a rotary motion, and as it does not return backwards, it cannot be termed a reciprocating motion, although partaking a little of the semblance of both. The second peculiarity is in differing from all other water meters in which the sole moving agency is the water pressure; in my contrivance the impelling force is derived from the water pressure and the force of gravitation, acting alternately and independently.

The measuring chamber is of the figure of a hollow cylindrical segment, whose end section is a little larger than a semicircle, terminating by a flat metallic plate or partition, forming a chord to the cylindrical segment or measuring chamber, within which the rectangular piston is connected to a spindle in the cylindrical axis, passing through a slot in the piston, in which a flattened part of the spindle fits easily,

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or the spindle itself is formed with a slot, through which the piston can freely slide. The thickness of the piston equals twice the excess of the cylindrical segment beyond the semicircle, and its length is confined within the plain surfaces of the ends of the cylinder. When the piston is inserted in a radial position, its outer extremity works in contact with the periphery of the measuring chamber, whilst its opposite and inner extremity works in contact with a hollow cylindric cavity, formed in the chord side of the chamber, of much smaller radius, but concentric with the greater circle.

When the cylinder is placed in a horizontal position, and the chord surface vertical, or in an inclined position, and the water being admitted through an aperture in the chord division below the central cavity and behind the piston, it gradually pushes the piston onwards and upwards, along the circular arc of the measuring chamber, guided truly in its course by the central spindle which revolves with it, whilst the inner extremity of the piston, which projects a little behind the spindle, sweeps the curve of the central cavity, to which it is accurately fitted; this movement is continued until the piston having reached the top, and nearly parallel with the chord surface, its axial end at the same moment having entirely passed out of the central cavity, the piston, acted on by gravitation, suddenly slides downwards, through or upon the spindle to the lower side of the chamber, and by this change in position the ends of the piston, which were previously in contact with the larger and lesser curves respectively, having changed places with each other, and at same time translated the axis of revolution from one end of piston to the other, it immediately starts on a second semicircular journey, pushed along by the water from behind, while the water in front of it is pushed on and outwards through the discharge port, situated in the upper half of the chord surface plate, and so on continuously.

In the absence of a sufficiently descriptive mechanical term, the motion of the piston may be likened to what takes place when turning a card over on one edge on a table—sliding it back to its original position—turning it again in

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the same direction on its opposite edge, and so on as before. A projecting part of the central spindle gives action to a registering index outside the instrument. The diagram and working model will show more clearly the character and action of the meter, which having only one single moving part, can scarcely be reducible to greater mechanical simplicity; and it will also be obvious, that from being entirely composed of true cylindrical and concentric curves and plain surfaces, its manufacture may be almost entirely the work of an ordinary turning lathe, which of all mechanical tools is the most correct, economical, and expeditious in the fabrication of every kind of work to which it can be made applicable.

Report of Committee.

"Your Committee, having considered the paper read by Mr John Reid on water meters, beg to report that in their opinion it gives a good epitome of the subject. The meters which have come into general use are therein well described, and represent, out of many inventions, those which in practice have been found to yield good approximate results. In comparing those with the meter invented by Mr Reid, and exhibited for the first time before this Society, the great difference between it and all the others, in respect to simplicity of construction, is at once apparent, and presents a marked feature in the new machine. The peculiar action of the piston, which enables valvular apparatus to be entirely dispensed with, is ingenious and novel, and exhibits a simplicity of action and character which comes out in strong contrast with all other existing water meters. As there will be comparatively little friction, the loss of head will be small, and the meter seems to be equally well adapted for registering hot as well as cold water. It can be so easily manufactured that the first cost must be trifling in comparison with the prices now charged for water meters, and this alone is a most valuable point in the invention. The objections may be embraced under two different heads:—First, under that of unequal wearing of the parts, which is an inherent defect in all meters having a rotary movement.

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In this meter the peculiar action of the piston, by which its ends alternately take the periphery and centre of the circle, will insure as nearly as may be an equal wearing of the sides of the piston. With the ends it will be different, as also with the sides of the semi-cylindrical casing, and it is apprehended that the piston will gradually shorten, and the sides of the cylinder nearest the periphery wear sooner than at the centre. It is not thought that this wearing action will be rapid, however, and a new piston could be put in so easily and cheaply, that the meter might be kept in repair for a long time at very trifling expense. The second objection is what may be termed the dead point of the piston, where the pressure of the water ceases to act, and gravitation comes into play. Grit sand, small pieces of straw or twigs, might prevent the falling of the piston, and either stop the action or allow unregistered water to pass; but this could only happen in meters of a small size, and may be nearly if not entirely prevented by a dirt trap. On account of the action of this meter being so different from any now in use, your Committee advance these opinions with diffidence, and consider such points can only be settled by actual experiment, extending over a considerable space of time. The attention of your Committee was called to a paper on water meters which, by a curious coincidence, was read at the Society of Arts in London five days previously to the paper read here. This helps to show the importance of the subject, and a reading of the London paper gives a good idea of the difficulties to be encountered in trying to get a good water measurer. A careful perusal of it confirms the favourable opinion formed regarding Mr Reid's invention, which will no doubt prove a formidable rival to any meter now in use. It would have been very satisfactory could the meter have been tested for accuracy of registration at different pressures, and with a varying delivery. This your Committee had not an opportunity of doing, but it would be interesting and valuable if one of them could be set to work for a time against a low-pressure meter, which registers with known accuracy, and it is hoped Mr Reid may be able to do this, and make the practical results known

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to the Society. Considering the admitted difficulties which have to be grappled with in the attempt to get a perfect water meter, and looking at the novel and peculiar motion which has been adopted in the present instance, pointing pretty closely as it does to the solution of a problem, we have much pleasure in recommending the matter to the favourable consideration of the Prize Committee.

(Signed) "DAVID MARSHALL.
"D. BRUCE PEEBLES."

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*Supplementary Notes of Experiments.**

In the paper on water meters, which I had the honour of reading before the Society on 27th February last, I took occasion to introduce a new design of my own for a water meter of a somewhat novel construction, whereby such instruments, which are very expensive, might be greatly simplified and cheapened.

On that occasion I had only got so far as a small working model for showing the principle of its construction and mode of action. It was intended to show its fitness for acting under high and low pressures. But as, unfortunately, the glass front for showing its interior had been accidentally cracked, I was unable to subject it to the strong pressure by which it was desirable it should be tested.

Besides the question of the possible behaviour of the piston under full pressure, a second and very important question arose regarding the loss of water in its passage through the instrument, by escaping past the sides and ends of the rectangular piston, which, having no packing, might prove to be a quantity constantly varying with the pressure, and therefore a continual source of error in its registration.

Since the date referred to, I have taken means to determine these two points; and with regard to the *pressure* question, I have prepared an instrument capable of bearing all the pressure to which it can be subject, and will now put it in action, when I expect it will show its paces satisfactorily.

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* Read before the Society 10th April 1871.

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Before doing so, however, let me advert to the leakage question, which at the date of my paper had never been the subject of any test or experiment. In the original paper I put it forth as a mere theory in the following words—"That the small amount of leakage that might pass the edges of the piston is not to be measured by the greater or lesser *head pressure of water,* but is obviously proportioned to the resisting *weight* of the piston only; and, therefore, the amount of such leakage per revolution or per action has to be added to the volume discharged by each stroke, and taken account of in the registering index."

Having a strongly constructed meter prepared with the view of satisfying myself on this important point, I thought I might ask permission of our secretary to submit the results to the Society, which having been granted, I take this opportunity of doing so.

I had the meter before me connected directly with the high pressure on the service pipe in my own house in the same manner as it is here. It was placed over a vessel of known capacity, into which the water, after passing the meter, was received and carefully measured.

For convenience, I fixed the limit of a series of experiments to fifty complete actions or descents of the piston in each case.

It being impossible in the circumstances to regulate and command certain definite altitudes of pressure, I adopted the best possible equivalent thereto, in putting the meter through its fifty actions in longer and shorter periods of *time,* with corresponding alterations in the rate of its *velocity.*

Without encumbering these notes with a lot of figures, I have only to report the result of the first and last of the series of trials, which turned out as follows:—

Putting the meter on what I think its full delivery-power—viz., about 1½ tons of water per hour—the fifty actions were performed in *six* minutes, giving a delivery of 33½ imperial gallons of water.

Again, giving it *twenty-two* minutes to perform the same number of actions, the delivery in this case was the same exactly as in the other—viz., 33½ imperial gallons.

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The actual amount of leakage depends, of course, on the proper and accurate fitting of the parts. In this instrument they are by no means so accurate as they might be; but whatever the percentage may be, I feel satisfied that my experiments demonstrate that, with any given meter of this construction, the leakage is to be measured only by the resistance offered by the piston, and will of necessity be a *constant quantity*, which, on being ascertained, shall be taken account of for registration by the index.

Supplementary Report of Committee.

"Your Committee beg to state that the favourable views expressed by them in their former report have been fully borne out. By the kindness of Mr Reid, your Committee were enabled to make an experiment regarding loss of water in its passage through his meter by escaping past the sides and ends of the rectangular piston, which might have proved to be a quantity constantly varying with the pressure, and thereby been a cause of error in registering. The experiment made by your Committee fully confirmed those made by Mr Reid, and clearly demonstrated that the leakage is to be measured only by the resistance of the piston, which is now proved to be an unvarying, and therefore constant quantity. Your Committee have every reason to believe that the action of the meter, extended over a considerable period, would give little or no variation from the results obtained by the comparatively short trial they were enabled to make. The experiment was made on a meter capable of passing 336 gallons of water per hour, and consisted of twenty falls of piston being made in 4⅓ minutes, and twenty falls in 7 minutes, when both quantities of water passed, being measured, were found exactly alike. Mr Reid's own trials were fifty falls of piston in 6 minutes, and fifty in 22 minutes, the delivery in both cases being measured were precisely the same in quantity. Your Committee beg to propose a hearty vote of thanks to Mr Reid, for his supplementary note on this important subject.

(Signed) "David Marshall, *Convener.*
"D. Bruce Peebles.
"George Cousin."

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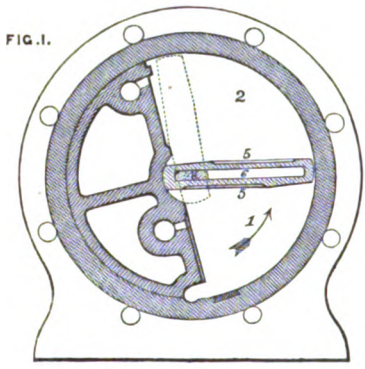
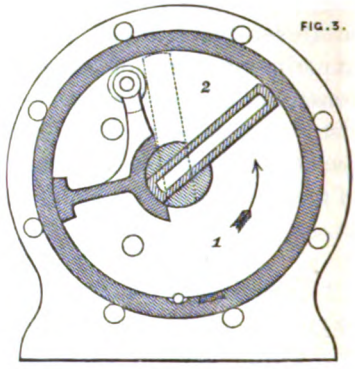
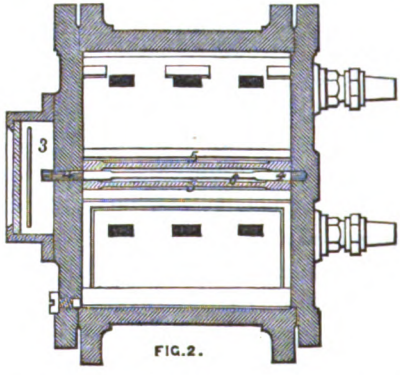
The annexed diagram and description will more fully show the construction and action of the instrument:—







Figures 1 and 2 are vertical sections at right angles of the instrument. Figure 3 is a modification. The measuring chamber 1, 2, is a cylindrical segment rather larger than a half-circle; the counter wheels or index are within a glass-fronted box, 3, and are acted on by the revolving spindle 4. The piston 5 is rectangular, and is connected to the spindle, passing through a slot in the piston, or the piston may itself pass through a slot in the spindle, as in figure 3. One edge of the piston works in contact with the inner surface of cylinder, whilst the opposite edge works into a concentric cylindric cavity, of smaller radius, formed in the chord side of the chamber. The chord side is vertical or inclined, the inlet for the liquid is below the central

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cavity, and the outlet is above it. When the piston is in the position shown, the liquid entering below lifts it upwards and round the course till nearly parallel with the chord, at which time the lower edge of piston escapes from the central cavity, and slides down by gravitation over or through the spindle, and thus translating the axis of revolution from one end of the piston to the other, when it again ascends by the pressure of the inlet from below, while the liquid above is forced outwards by the ascending piston through the outlet port above. The opposite sides of the piston at the ends are slightly bevelled off to ensure the piston sliding down just before it comes in contact with the chord surface. A small cavity below is for collecting sediment, which is let off by a screw plug.

Notice of a New Form of Intermittent Light for Light-houses. By ROBERT LOUIS STEVENSON.*

The necessity for marked characteristics in coast illumination increases with the number of lights. The late Mr Robert Stevenson, my grandfather, contributed two distinctions, which he called respectively the *intermittent* and the *flashing* light. It is only to the former of these that I have to refer in the present paper. The intermittent light was first introduced at Tarbetness in 1830, and is already in use at eight stations on the coasts of the United Kingdom. As constructed originally, it was an arrangement by which a fixed light was alternately eclipsed and revealed. These recurrent occultations and revelations produce an effect totally different from that of the revolving light, which comes gradually into its full strength, and as gradually fades away. The changes in the intermittent, on the other hand, are immediate; a certain duration of darkness is followed at once and without the least gradation by a certain period of light. The arrangement employed by my grandfather to effect this object consisted of two opaque cylindric shades or extinguishers, one of which descended

* Read before the Society on 27th March 1871, and awarded the Society's silver medal, value three sovereigns.

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from the roof, while the other ascended from below to meet it, at a fixed interval. The light was thus entirely intercepted.

At a later period, at the harbour light of Troon, Mr Wilson, C.E., produced an intermittent light by the use of gas, which leaves little to be desired, and which is still in use at Troon harbour. By a simple mechanical contrivance, the gas jet was suddenly lowered to the point of extinction, and, after a set period, as suddenly raised again. The chief superiority of this form of intermittent light is economy in the consumption of the gas. In the original design, of course, the oil continues uselessly to illuminate the interior of the screens during the period of occultation.

Mr Wilson's arrangement has been lately resuscitated by Mr Wigham, of Dublin, in connection with his new gas-burner.

Gas, however, is inapplicable to many situations; and it has occurred to me that the desired result might be effected with strict economy with oil lights, in the following manner:—

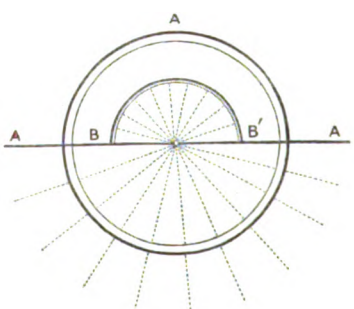

Fig. 1.

In fig. 1, A A A represents in plan an ordinary Fresnel's dioptric fixed light apparatus, and B B′ a hemispherical mirror (either metallic or dioptric on my father's principle) which is made to revolve with uniform speed about the burner. This mirror, it is obvious, intercepts the rays of one hemisphere, and, returning them through the flame (less loss by absorption, &c.), spreads them equally over the other. In this way 180° of light pass regularly the eye of

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the seaman ; and are followed at once by 180° of darkness. As the hemispherical mirror begins to open, the observer receives the full light, since the whole lit hemisphere is illuminated with strict equality ; and as it closes again, he passes into darkness.

Other characteristics can be produced by different modifications of the above. In fig. 2 the original hemispherical mirror is shown broken up into three different sectors, BB′, CC′, and DD′ ; so that with the same velocity of revolution the periods of light and darkness will be produced in quicker succession. In this figure (fig. 2) the three

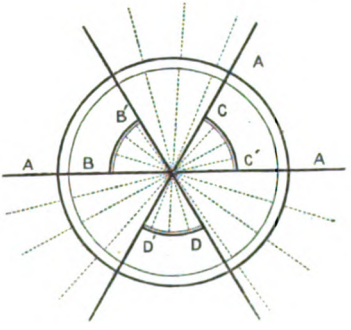

Fig. 2.

sectors have been shown as subtending equal angles, but if one of them were increased in size and the other two diminished (as in fig. 3), we should have one long steady illumination and two short flashes at each revolution. Again, the number of sectors may be increased ; and by varying both their number and their relative size, a number of additional characteristics are attainable.

Colour may also be introduced as a means of distinction. Coloured glass may be set in the alternate spaces ; but it is necessary to remark that these coloured sectors will be inferior in power to those which remain white. This objection is, however, obviated to a large extent (especially where the dioptric spherical mirror is used) by such an arrangement as is shown in fig. 4 ; where the two sectors, WW, are left unassisted, while the two with the red screens are reinforced respectively by the two sectors of mirror, MM.

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Another mode of holophotally producing the intermittent light has been suggested by my father, and is shown in fig. 5. It consists of alternate and opposite sectors of dioptric spherical mirror, MM, and of Fresnel's fixed light apparatus, AA. By the revolution of this composite frame about the

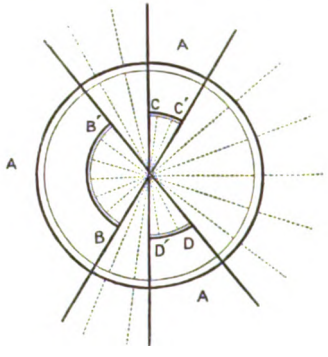

Fig. 3.

burner, the same immediate alternation of light and darkness is produced, the first when the front of the fixed panel, and the second when the back of the mirror, is presented to the eye of the sailor.

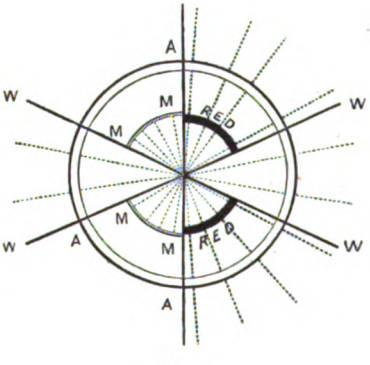

Fig. 4.

One advantage of the method that I propose is this, that while we are able to produce a plain intermittent light; an intermittent light of variable period, ranging from a brief flash to a steady illumination of half the revolution; and

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finally, a light combining the immediate occultation of the intermittent with combination and change of colour, we can yet preserve comparative lightness in the revolving parts, and consequent economy in the driving machinery. It must,

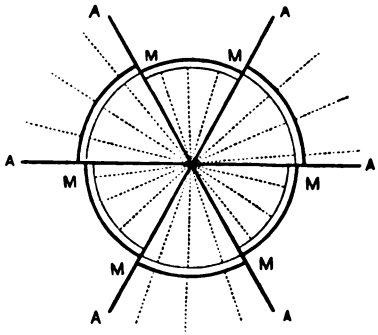

Fig. 5.

however, be noticed, that none of these last methods are applicable to cases where more than one radiant is employed: for these cases, either my grandfather's or Mr Wilson's contrivance must be resorted to.

Indicator for Weighing-Machines. By JAMES MACKENZIE, Grange Place, Edinburgh.*

It may not be inappropriate to preface the description of this apparatus by mentioning a few of the arrangements in ordinary use for determining the weights of mercantile commodities, even although they may be, for the most part, already sufficiently well known. A glance at these, however, may serve to make clearer some portions of the mechanical arrangements which have more particularly to be described. The ordinary equal-armed balance, with scales and weights, comes first—the simplest and most perfect arrangement, and familiar to all. A modification of Roberval's balance (which consists of two equal-armed levers, the centre of the one placed exactly above that of the other, the levers being joined at their extremities by upright con-

* Read before the Society on 10th April 1871, and awarded a Keith Prize, value ten sovereigns.

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necting rods, which support the scale-pans), is also commonly used, particularly as a letter-balance; and, more especially for this latter purpose, an adaptation of the ancient steelyard, or unequal-armed balance, is also found useful. From the example shown, it will be seen that in using it no separate and varying weights are requisite; one weight, capable of traversing the longer arm, being sufficient. The arm is graduated according to requirement, and upon the article to be weighed being placed in the scale, the counterpoise has to be shifted until equilibrium is attained, when the weight can be read off. Attention may be called to this form of weighing-machine, as it will help to illustrate what has to be described further on. There is yet another form of balance which is occasionally used, that known as the "bent-lever" balance. So far as can be ascertained, it is little used except in paper-mills and stationery warehouses, where it is found serviceable for weighing single sheets of paper, with the view of determining the weight of the same quality of paper per ream. The example shown is an adaptation of the bent-lever balance to the weighing of letters and book packets. This apparatus requires neither separate nor sliding weights, but upon placing in the scale the article to be weighed, the longer arm, carrying the counterpoise and pointer, rises in front of the graduated arc, until of itself it attains equilibrium, when the weight may be read off at once. Further on this arrangement also will be reverted to.

The form of weighing-machine, however, which is more particularly to be considered at present, is that intended for the weighing of more than ordinarily heavy or bulky articles, and loaded carts or railway waggons. Such a machine may be briefly described (beginning at the end instead of the beginning) as a plate or "weigh-bridge" laid flush with the surface of the adjacent ground, if intended for cart-weighing, or provided with rails continuous with those of the "siding," if intended for railway purposes. This weigh-bridge rests upon a simple combination of levers underground, by means of which the pressure of the load is communicated to the aboveground lever or steelyard, which carries a sliding

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counterpoise, exactly as in the case of the steelyard letter-balance already referred to. The aboveground lever is graduated to hundredweights and fractions, commonly in railway machines, up to five tons. In using the machine as adapted to cart-weighing, the method is simply to bring the cart to rest upon the weigh-bridge, and shift the counterpoise to a greater or less distance from the fulcrum, as the load may be greater or less, until equilibrium is attained, when the weight is read off. In the weighing of railway waggons it would be very desirable to have the same process followed, but there are difficulties:—in the first place, the time required for the weighing of each waggon separately could hardly be spared, because, unlike cart-weighing, where the operations may be spread over the whole day, the times of weighing are comparatively few, but at each there may be twenty, thirty, or more waggons to be weighed, and detention of the trains must be as far as possible avoided. Again, the waggons are too unwieldy to be easily controlled except by means of the locomotive engine, and it would be all but impossible for the men to bring each waggon to rest exactly upon the weigh bridge, even if the waggons were separated, except with too great expenditure of time.* The practice, therefore, is to cause the engine to propel the waggons in train, at a low rate of speed (but without intermission) over the weigh-bridge, and, while each one is traversing, the attendant is required to shift the counterpoise until the correct weight is indicated, read that off, note it down, and be ready for the next waggon, when the same operations are repeated, and so on until all the waggons in the train are weighed. The performance of this operation with any approach to correctness is, as may readily be believed, no easy matter; but, indeed, the description given is apt to convey rather too favourable an idea of what the process really is. The words, "while each waggon is traversing" the weigh-bridge, require to be considered, because it must be

* Since writing the above, I have found that it is common among the English railway companies actually to follow the method of separate weighing, extra men and horses being kept at the weighing stations for the shifting of the waggons.

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remembered that until all the wheels of a waggon are upon the weigh-bridge, no attempt at weighing can be made; and by the time the hind wheels are on, the leading wheels are nearly off, so that in reality it is while the waggon passes over perhaps only a few inches that its weight can possibly be determined. But this is not all. As already stated, the sliding counterpoise by itself is capable of indicating (in most cases) only up to five tons, but many waggons are little, if at all, short of that weight when empty. A scale-pan is therefore suspended from the extremity of the steelyard, and a series of auxiliary weights provided for the use of the attendant, who must have sufficient experience to enable him at a single glance to estimate the probable weight of each waggon as it comes forward, and he must lay on or take off weights accordingly. Supposing, for instance, that weights representing five tons were in the scale-pan; the counterpoise can then indicate any weight from five up to ten tons. But perhaps a waggon comes forward which the weigher judges will exceed the latter weight. In this case he must instantly lay on as much additional weight as will admit of the counterpoise's overtaking the heavier load. Again however, the waggon next approaching may be comparatively light, and if so, a sufficient weight must be instantly withdrawn from the scale-pan to bring the counterpoise back within the required limit. During all this time the waggons are going steadily on; the entrance and exit of each pair of wheels must be closely watched; and it may easily be imagined that before accurate results can be expected, the attendant must have had considerable experience, and attained very considerable dexterity in his manipulation of the apparatus. Nor must it be forgotten that he must keep correctly in mind the sum of the auxiliary weights in the scale-pan at the time of the passing of each waggon, because his reading of the graduation must vary with each increase or decrease of these weights. The work, there is reason to believe, is upon the whole very creditably performed, but yet mistakes are by no means infrequent, and the settlement of disputes caused by such mistakes is rather troublesome. Some improvement toward rendering the

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operation of weighing more simple, giving more trustworthy results, and making the settlement of disputes more easily attainable, seemed to be called for, and the means by which it is proposed to meet, as far as possible, those requirements, may now be described.

The principle upon which the contrivance is based is this:—instead of the load being determined by the distance along the steelyard, to which the counterpoise has to be removed, it is determined by the height to which the extremity of the steelyard is allowed to rise. The sliding weight and the scale-pan are taken off, and a single counterpoise is attached to the extremity of the steelyard, but attached in such a manner that its resistance increases with every hairbreadth of rise given. Equilibrium is thus attained without any action whatever on the part of the attendant, the arrangement being so far entirely self-acting. Now, if the contrivance were carried no further, all the results of the ordinary system would be completely attained, as by merely providing a pointer and a fixed index, the weight could be at once read off; but the further action of the apparatus will presently be described. In the meantime, the method of causing the counterpoise to increase in its resistance upon each increase of the load may be considered. Various methods suggested themselves as likely to effect this with greater or less facility, such as the bent-lever balance, Salter's spring balance, a counterpoise immersed in mercury or other fluid (which counterpoise will, of course, increase in its resistance as it is lifted from the fluid, until it attains its maximum when entirely withdrawn), and other methods which need not at present be described. The spring balance was, upon the recommendation of one of our railway engineers, actually tried, but being found somewhat uncertain and unsteady, unless some special means of controlling its oscillations were adopted,—it was set aside, and the adoption of some form of accumulating weight determined upon. The first form contemplated was that of the bent-lever balance, but there was the objection that with the ordinary form of that balance it is impossible to get equal graduation of the index without some com-

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pensating movement, which could not very conveniently be introduced in the larger apparatus. In the ordinary bent-lever balance the counterpoise certainly increases in its resistance as it rises, but not in equal proportions, *e.g.*, according to the angle at which the shorter arm is set, the graduation will either be comparatively minute at starting, constantly getting wider and wider up to a certain point, and then gradually decreasing; or it will begin with comparatively wide degrees, gradually getting more and more minute. For this reason it is customary, in constructing this form of balance, to graduate the arc experimentally. In the example shown, however, an excentric arc, with a flexible chain, is introduced, the curvature of the arc being such, that while the counterpoise in its rise is decreasing in its proportionate resistance, the load in the scale-pan is proportionately decreasing in its leverage, and thus the index can be, as in the present instance, graduated equally throughout. But the application of this excentric arc to the inverted arrangement necessary in the waggon steelyard would be somewhat difficult, and even if effected, it is probable it would be, to use an expression which has been applied to mechanics, decidedly "ungrammatical." To bring about, therefore, the same result in the larger apparatus, the weight is suspended from the steelyard,—not directly, but through the intervention of a vibrating sector or bell-crank, and not attached to a rigid bar, but to a flexible strap or chain, which adapts itself to the curve of an arm projecting from the sector, the curvature being such as to give the same effect as the excentric arc referred to as applied to the bent-lever balance. The correct form of this curve is found to be the involute of the circle of which the inner flange of the sector is an arc; or indeed it might be, within reasonable limits, the involute of any circle having the same centre. By this means the steelyard is made to rise through an exactly equal distance for every equal increase of load, and it only remains to provide the means of recording the weight indicated. This part of the contrivance may be very shortly described. The rise allowed to the end of the steelyard is only five inches, which would

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necessitate too minute sub-division of the index to be convenient in practice. The arms of the sector are therefore produced to double the distance from the centre, and thus at the outer end the rise becomes one of ten inches, and as a range of ten tons is held to be sufficient, the index (which is placed exactly above the outer extremity of the sector) is graduated to one inch to a ton. From the outer flange of the sector a rod is suspended vertically, by means of a metallic cord or strap, which rod, of course, rises and falls as the sector is acted upon by the steelyard—rising and falling exactly in front of the index. The upper portion of the rod is made flat, and is at its upper end bent over, to the extent of about an inch, at right angles, the bent portion being serrated on its edge. The index is not fixed, but is in the form of a printed diagram placed upon a revolving cylinder. The diagram is ruled horizontally to inches and tenths (each tenth, of course, representing two hundredweights), and also vertically in columns, each about as broad as the serrated portion of the pointer-rod, and each representing a waggon. The attendant controls the steelyard by means of a cross handle, which prevents any movement until the proper moment, *i.e.*, until the first waggon is in the correct position on the weigh-bridge, the hind wheels just entering. He then steadily withdraws the controlling handle, and the steelyard rises until the counterpoise reaches its equilibrium, which it immediately does, the pointer rising in front of the first column of the diagram at the same time. The last portion of the travel of the controlling handle releases a hammer which falls upon the pointer and causes the serrated edge to perforate the paper at the place in the column at which the waggon's weight is indicated. At the same moment a fresh tooth of a ratchet on the base of the cylinder is taken up by a pawl, and upon the handle being returned (which is done when the leading wheels are just leaving the weigh-bridge), the cylinder advances a tooth's length, so as to oppose the next index column to the serrated pointer. The operation is repeated for each waggon in the train, and when all are past, the attendant enters in his book the weights as marked in the diagram, and the

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latter may be kept as long as necessary for reference in case of dispute. The working of the apparatus is exceedingly simple, being nothing more than the withdrawing and returning of the controlling handle at the proper times, the weigher's attention being directed to the wheels as they come forward. The same observation is, of course, necessary under the present system, in fact, is a matter of the utmost importance, and it may be held to be a good result that it becomes possible for the weigher's attention to be exclusively directed to it.

The woodcut will explain the form and action of the apparatus :—

A. Extremity of the steelyard.

B. Attachment for the scale-pan required for auxiliary weights under the present system—to which attachment the indicator is coupled.

C. Controlling handle, with a projecting branch, angled so as to admit of the gradual and steady rise of the steelyard.

D. Vibrating sector, attached by a hook and chain (or metallic cord or band) to the steelyard.

E. Curved arm projecting from the sector, and controlling the lower end of the chain or cord.

F. Counterpoise, raised by the chain or cord from the sector.

G. Pointer rod, suspended from a produced portion, H, of the sector.

I. Cylinder carrying the graduated diagram.

K. Hammer worked by the controlling handle, to strike the pointer through the diagram.

L. Ratchet on the base of the cylinder, acted upon a pawl taken up and released by the projecting branch of the controlling handle.

N.B.—When the indicator is in use, the working parts are entirely covered in, and placed under lock and key, only the cylinder and controlling handle being accessible.

Besides railway weighing, the apparatus is capable of other applications. For cart-weighing machines, or any machine in the use of which the immediate reading of the weight is sufficient, the recording mechanism may be omitted, and the pointer and fixed index, before referred to, adopted; the arrangement then becomes one of extreme simplicity. The index may be placed upon the weigher's desk, so that his book may lie just in front of it, and without his having to leave his seat, he can take down the weights of carts or other vehicles, with less risk of error than at present, from the greater distinctness, and more convenient reading, of

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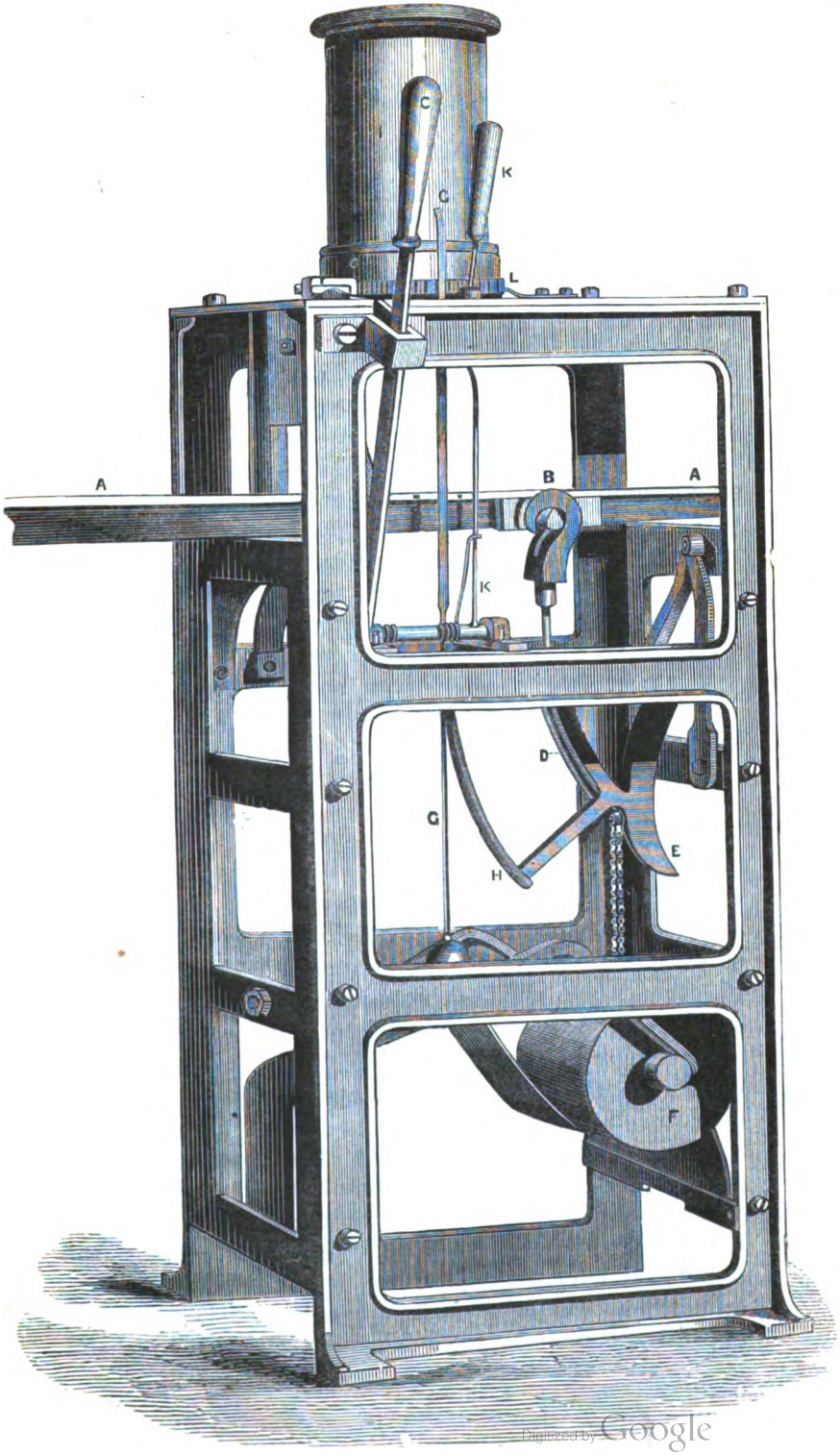

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the indications. The principle is also applicable to the weighing of small articles, such as letters or post-packets of any kind. The letter or packet has merely to be placed in the scale, and the pointer instantly shows the weight upon the index, the position of which makes the reading off very convenient, as may be seen from the example shown.

But the diagram system can be greatly extended, so as to be applicable to such weighing as that required at collieries, weighing hutches of coal as they come "to bank." To provide for this, two cylinders would be used—one to give, the other to take—so that there would be room for a thousand weighings, or more if required. The weigher would only have to mark each man's number, and, if necessary, the mark for the particular quality of mineral, at the top of the column showing the weight sent up, and any dispute in regard to such weight might, it may be presumed, be easily settled by reference to the diagram.

It may be the opinion of some that, to be complete, the contrivance should be entirely self-acting. This has not been overlooked, and can be readily undertaken if required. One way in which it could be done may be briefly stated. A tappet or stud would be placed at the exit end of the weigh-bridge, to be acted upon by the wheel-flanges, so as by suitable connexion to give motion to a pair of ratchet-wheels, fixed together, and revolving upon a common axis. The first ratchet would get a tooth's travel upon the passing of every pair of wheels; the hammer being worked by the other, which must have just half the number of teeth, and thus the hammer would fall at the passing of each alternate pair of wheels, which is all that is required. Of course, the lever must be locked by a controlling handle or otherwise, between the times of weighing trains, and the machine would have to be capable of being thrown out of gear at once, if anything untoward were to occur. Six-wheeled waggons (which, however, are seldom if at all used for coal traffic) have to be provided for at present, and would still have to be provided for. But the self-acting arrangement would be necessarily more complicated, more expensive, more liable to derangement, and would probably

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be inconvenient in the event of steelyard repairs being necessary. Besides, the attendant must be present at all events, as the numbers and tares of the waggons must be taken down before the weighing begins, precisely as at present, and he may as well be looking after the machine as standing idle. It may also be advanced that the machine might be made more compact, but as the frame must be provided, to keep the movements at the proper elevation, there would be nothing gained by packing the mechanism more closely, and the greater the facilities for getting at the various parts the better.

The inventor is not aware of the principle of the involute having been applied in the same manner before, but he has recently been shown, through the kindness of Mr Ritchie, a balance somewhat similar in principle, which had been used for paper weighing (like the bent-lever balance described) but the method of application is widely different. It consists of a revolving dial upon a fixed centre, to which latter a pointer, reaching to the circumference of the dial, is rigidly attached. A rather curious pair of cambs or "snails" are fastened to the back of the dial—the one having a cord attached, which carries the scale, the other carrying the counterpoise in the same manner. The dial is graduated on its circumference, and upon the scale being depressed, the dial revolves until the indication of the weight stands opposite to the pointer.

In conclusion, it may be stated that as regards facility and accuracy in railway weighing, there is the best reason for confidence in the correctness of the principle,* while the advantage of having the weight of each waggon marked permanently and indelibly, by the waggon itself, is undoubtedly very considerable. One noteworthy recommendation is that to admit of the application of the

* The indicator has been, up to the present date (10th April 1871), upon trial at one of the principal weighing stations of the North British Railway, for nearly six months; and the results have been all along, and are still, reported as quite satisfactory. The weigher at another of the stations (Polkemmet), at which an indicator is now (August 1871) in use, writes that he weighs at an average rate of ten waggons per minute. This, he says, "can be done easily, and with perfect accuracy."

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indicator, there is no necessity for any alteration whatever being made upon the present weighing-machine; the indicator can be with little trouble attached to any machine, and, in the event of derangement (to which it is not very liable, being simple and capable of being substantially put together) it can be unshipped upon a few minutes' notice, the sliding weight and scale-pan replaced, and the present system reverted to at once.

Note.—I have to acknowledge the valuable services of Mr David Morgan, locomotive superintendent for the northern section of the North British Railway, who has, from first to last, shown me the greatest kindness and attention, not only in placing at my disposal the weighing-machine at the Burntisland works, for the prosecution of the preliminary experiments; but also in the most friendly manner assisting me by preparing the first drawings, and himself superintending the construction of the original model. Indeed, but for the encouragement given by him, the matter would probably not have been proceeded with at all. I have also to acknowledge the able assistance of Mr John B. Weir, engineer and draughtsman, who constructed the model and small weighing-machines exhibited, and who also made the working drawings for the full-sized apparatus.

On the Progress of Invention. By Professor T. C. Archer, Director of the Museum of Science and Art.*

In this paper I do not intend to give a history of all the improvements which are daily taking place in every branch of industry, nor would it be possible if I wished to do so; neither my ability or time would suffice for such a task. I simply propose, after the admirable plan of Dr Stevenson Macadam upon several occasions, to describe, as well as I can, the new inventions of various kinds which have most interested me in my later journeys amongst the manufac-

* Read before the Society on 24th April 1871, and awarded the Special Thanks of the Society.

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turing districts, or which have attracted my notice at home during the last year.

The first class of subjects to which I shall call your attention are connected with metallurgical operations, which the enormous increase incessantly going on in our manufactories and constructions of all kinds render as interesting as they are important. The two minerals of the greatest value in this kingdom are, of course, coal and iron; the working of both are sources of considerable anxiety. With respect to the former, a well-grounded desire exists to economise its consumption as much as possible, both from the conviction which better education has greatly increased, that *waste is a disgrace*, and that the uncertainty about the future production of this invaluable material renders it a matter of prudence to economise it. Iron, however, seems inexhaustible; but the more abundantly it is produced the greater the demand becomes, and with it the necessity for improving the means of reducing the ores, and bringing the crude metal into the states necessary for the manufacturer. Hence the economical combustion of coal and the cheap smelting and puddling of iron are leading points of interest, and are perpetually stimulating the inventive genius of the country.

I will call your attention to two or three inventions which have arisen out of the considerations which I have just mentioned. Firstly, Siemen's Regenerator, which was described by Dr Macadam as being in use at the St Helen's Glass Works. It is now about eight years since this ingenious and very valuable invention was patented in this country, and its first application on a large scale was, I believe, at the glass-works of Messrs Lloyd & Summerfield, of Birmingham, where I first saw it in use. Every year since then has witnessed its application to other purposes, until now it is in extensive use in many of the great iron-works, and notably in some of the puddling furnaces, where it is found to act well, and with so great an economy of fuel, that it is said to save sometimes as much as 50 per cent., besides saving much labour in feeding the furnace.

Another ingenious and still more economical invention

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for saving our stores of fuel is that of Mr Crampton. It consists of a specially constructed furnace, into which the coal is blown in a finely pulverised state, and ignited in presence of a properly proportioned amount of air sufficient for its complete combustion. The consequence is a most intense degree of heat, sufficient for all the purposes of the metallurgist, and a complete absence of one of our greatest evils—"*smoke.*" This process will, of course, give value to what has hitherto been considered the waste and even the nuisance of our coal mines. Crampton's furnaces are already working successfully in the great engineering department of the Royal Arsenal at Woolwich, and also in the large iron-works at Bowling, in Yorkshire.

As the differences in the three states in which iron is used consist in the presence or absence of carbon, that is to say, in cast-iron there is an excess of that element, in steel only a small percentage, and in malleable iron it is absent. It has for a very long time been a great desideratum to produce the iron from the ore in any one of these three states by a first operation, instead of the old-fashioned plan of first getting cast-iron; then removing from it the carbon, and so producing malleable iron; and then, if steel be wanted, to replace the necessary 1¼ per cent. of carbon.

You are all doubtless aware that Mr Bessemer practically solved the difficulty with respect to steel, and, by his remarkable invention, succeeded in producing steel of good quality, and so easily, that it now takes the place of iron in some of our largest operations. I cannot illustrate this better than by telling you that in the stupendous works of Sir John Brown & Company (Limited), of which I shall have more to say by and by, no less than 1400 tons of steel rails are produced weekly, their production of this comparatively new kind of rails having exactly doubled within the short period of the current year.

The Bessemer process consists in forcing atmospheric air through molten cast-iron. The result is, the oxygen of the air enters into combustion with the carbon of the iron, and burns it out, producing the effect of a magnificent display of fireworks. When completely burned out, the addition of

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a portion of cast-iron, containing a known quantity of carbon, restores the small percentage necessary to convert it into steel. It is then poured out into ingot moulds, and, as soon as cool, is fit for use. For a long time there were certain drawbacks to this system, arising from a want of uniformity of quality in the steel so produced; but the improved methods of applying the invention, and the now universal practice of analysing the materials, have produced most satisfactory results; and within the last few months these advantages have been greatly aided from a quarter from which help was not expected—I mean the use of the spectroscope, which is now constantly used, and is found to have an important practical value. By it the flame and brilliant corruscations produced by the combustion of the carbon and other combustible constituents of the iron are carefully examined, and thus an important means is furnished of checking the chemical analysis.

A process known as "*Henderson's*" is beginning to attract notice; it is for producing *malleable* iron direct from the smelting furnace, and, if required, converting it into steel by the addition of a proper proportion of melted cast-iron, as in the case of the Bessemer process. In this process the iron, as it runs from the smelting furnace, is received in a vessel in which are placed small quantities of powdered fluor-spar and the oxide of titanium, or some other oxides; the results are the almost complete removal of the impurities of the metal, an active combustion being induced which consumes the carbon, silicon, phosphorus, and sulphur, leaving a fine quality of malleable iron. To those who, like myself, have, from time to time, to visit the manufacturing districts, nothing is so astonishing as the mighty strides made by our great works. The wonders of yesterday are forgotten in the still more gigantic operations of to-day. In 1862, one of the largest works for manufacturing wrought-iron was that of Mr John Brown (now Sir John Brown & Co., limited), and he exhibited in the International Exhibition an armour plate which was considered one of the greatest metallurgical feats of the age. It was 21 ft. 8 in. × 4 ft. 2 in. × 6½ in. The largest steam-hammer used in

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its construction had a stroke of 6 tons, and the planing machines, by which its edges were beautifully planed, were considered marvels of mechanical skill. Now in the same work thousands of tons of armour plates are made 9, 12, and 13 inches thick, hammers with 17-ton stroke are used to consolidate them, and in March last, I saw ten plates lying, side by side, and all being cut by one enormous planing machine.

A representation of these immense works, which cover nearly 30 acres of land, hangs before you. The chief productions are armour plates, steel rails, railway carriage springs, railway wheel-tyres, and occasionally chilled shot for the War Department.

Their appliances for producing the vast quantities of these articles which are required from them will be best understood if I give a list of the various machinery, &c., in use there:—

39 Steam hammers.
103 Engines, donkey-pumps, rail-saws, &c.
3 Accumulators for hydraulic machines,
3 Bending presses for armour plates, and
2 Pumps for do.
} Hydraulic.
19 Rolls and tyre-rolling machines.
95 Travelling and other cranes and hydraulic hoists.
35 Planing machines.
32 Drilling do.
12 Slotting do.
5 Screwing do.
81 Weighing do.
5 Testing do.
22 Spring-making do.
38 Lathes.
16 Grindstones.
25 Shearing and punching machines.
36 Turnstiles.
7 Fans.
6 Helves, and
3 Tilt hammers.
1 Coiling machine.

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1 Blocking machine.
1 Punching do.
1 Rail-splitting do.
1 Mortar mill.
1 Stone-breaker.
1 Set of boiler-plate bending-rolls.
2 Ten-ton } Bessemer converters, with cupels, &c., com-
4 Five-ton } plete.

This array of mechanical power, in addition to the labour of between two and three thousand men, represents a producing force which only fifty years ago would have been deemed incredible. In the enumeration just given of machines, &c., I have mentioned a coiling, a blocking, and a punching machine, and also tyre-rolling machines. These are all for the purpose of producing tyres for railway carriage wheels. The processes are very interesting, and have lately been greatly improved At first the tyres of such wheels were made in lengths, and welded on a sort of mandril which was of the required size. Now there are two processes employed quite different. One is for iron, the other for Bessemer steel tyres. In the first the iron is rolled into flat bars, with tapered ends; they are made as nearly as possible of equal weight, which, if deficient or in excess, has to be rectified by the subtraction or addition of what is wanted. These bars are then coiled by the coiling machine, so as to look like a flattened spring, this is afterwards welded so as to form a large ring, which is then put in the tyre-rolling machine, and made to the size required with the proper flanged section.

By the other process a certain quantity of the steel is blocked by the blocking machine into a flat cake. The punching machine takes out a large round disc from the centre of this cake, and the blocking machine then works the ring of steel which remains into a rudimentary tyre with the edge flanged. This is completed afterwards to the required size by the tyre-rolling machine.

At Oldham, near Manchester, is the vast manufacturing establishment of Platt & Company, employing 7000 men. The extent of shafting for driving the various machines

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exceeds eight miles in length. The staple manufactures are looms, mules, and other spinning and weaving machinery. The mechanical appliances of this immense establishment are, of course, very various, and many of them of great interest. The foundry is said to be the largest in the world, and the operations carried on in it are very numerous, but mostly on a small scale, rarely anything larger than the frame cheeks of a power-loom being required. I noticed one operation in the fitting shop where all the five holes in several of these frame cheeks were being cut to gauge at the same time by a new contrivance. Adjoining the machine works is one for brick-making belonging to the same firm, the operations in which are carried on by an enormous brick-making machine, on Mr Platt's patent, which turns out ready for use 47,000 bricks per week, of very superior make to any in ordinary use. The clay, nearly dry, is fed through a large hopper, and passes between powerful rollers, which reject all large stones, and then passes down a slightly inclined Archimedean screw in a cylinder 60 feet long. At the end of this cylinder it is raised 6 feet by elevators, and passes through a second pair of rollers, which break it up still finer, and reject any large stones which escaped the first pair; it then descends again through another slightly inclined cylinder with screw, called the drying cylinder, through which a very strong draught of cold air passes. When it reaches the end of this cylinder, it is met by another Archimedean screw, in a trough placed at right angles to it, and is by it carried to an arrangement for separating the small stones and still further comminuting the dry clay, which then passes up elevators to the grinding machine, where it is reduced to a coarse powder. This powder is then sent gently down shafts to feed the brick moulds, jets of steam also being admitted into the shafts, so that the clay powder receives sufficient moisture to combine it under the pressure of the plungers, which drive it into the moulds four at a time. As the plungers rise, the bricks are lifted up and the mould cleared for more. They are then removed to the kilns and burned.

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At Birmingham one or two recent changes have been made in the art of electro-deposit.

Until lately the enormous magneto-electric machine, which was shown by Berlioz & Co., of Paris, in the French department of the Exhibition of 1862, has been used by the Messrs Elkington for producing the electric current used in their deposit works. This machine, originally invented with a view to lighthouse illumination, cost, I believe, £11,000, and occupied a space of about 10 feet square. It has now been superseded by one of an entirely new construction, by Mr Wylde, of Manchester, of extreme simplicity and immense power, but only occupying a space of 2 square feet. Two sizes are in use—in one the magnets make 2500 revolutions per minute, in the other 1600. The result of this change is, that deposits, which formerly took twenty-eight days for their completion, are now done in nine days—in other words, this apparently slight change has trebled the producing power of this, the largest establishment of its kind in the world.

The Birmingham Plating Company, very recently established, have introduced with great success a method of coating iron (either cast or wrought), brass, copper, or any other metal, with nickel at so cheap a rate that it must come into very extensive use. Its beauty is seen in the articles I have placed before you.

In textile manufactures improvements are continually being introduced. Amongst the most notable ones recently made are some which I examined in the admirably conducted works of the "Patent Cloth Company," at Leeds, where the whole of the fabrics are produced by felting. Felted goods of great beauty have long been produced, especially by this firm, but they wanted strength. This quality has now been obtained by a beautiful but complicated arrangement, by which the broad continuous sliver from the carding machine is crossed transversely by a sliver of equal width, so that the fibres of wool are laid at right angles to each other, thereby greatly increasing the strength of the fabric in both directions. Then, again, another method of producing a very strong, and at the same time

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a cheap cloth, is by placing an openly woven web of cotton between two slivers of wool—the upper one of fine quality, the lower of inferior—and then, by submitting the whole to the felting process, the wool fibres of each side pass sufficiently through the cotton to combine and form a cloth which can hardly be torn. The beautiful petticoat I show is a manufacture of the same firm under an American patent, and is made in one piece without seams; in texture it is equal in softness to the finest flannel.

At the Messrs Forster's mills at Queensbury, near Halifax, I lately had the opportunity of seeing the beautiful circular carding machine of Mr Noble in active use. This appears to be a great improvement, in the amount of work done, upon the ingenious one invented some years since by Mr Lister; both were working side by side, the latter with two or three modern improvements. These machines are, however, far too complicated to be described verbally. In the same works I witnessed the operation of several very ingenious and effective machines for making the small paper tubes, on which the cops of woollen and worsted yarns are wound for the export trade. In these machines the paper was pasted, rolled on a mandril consisting of two parts placed end to end, which, when sufficient folds of paper were rolled on and cut off from the following supply, which is on a reel, were by the action of the machine pulled apart, dropping the finished tube of paper, and then immediately coming together to receive another. About 40 per minute are made by each machine.

There is nothing more remarkable in the history of the woollen manufactures of the present century than the imitations which have been made, during the last few years, of the skins of various animals, and this speciality has almost entirely localised itself around Huddersfield. These imitations consist of seal skins, Astracan lamb skins, dog skins, the fur of the chinchilla, and others, all of which are now made with such surprising skill that they are easily mistaken for the real skins. The same fabrics are also made into a great variety of fancy goods, by dyeing, figuring, &c. So interesting is this manufacture, that it may be worth

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while to say a few words upon the methods employed to produce the various effects. Taken in the order in which they are mentioned above, the first is *seal skin*, or an imitation of the exquisitely soft brown silky fur of the fur seal.

This fabric is woven with ordinary yarns, either all-wool, or cotton warps and woollen wefts, with an intermediate surface-yarn of mohair, the arrangement of which is peculiar. It is loosely twisted weft yarn, which is shot alternately with the back weft, but only passes under one or two threads of the warp, at pretty long intervals, in which the longer and transverse threads are those of the mohair weft, and the shorter ones crossing them are those of the warp; these, of course, are also crossed with the weft-threads of the back. When the whole web is completed, it is taken to the cutter, who uses a knife of peculiar form, the sharp edge of which he inserts under the overlying mohair yarn, and presses it forward in a curved direction, cutting the yarn clean through as he proceeds. The result is that the cut threads immediately rise and partially untwist themselves, forming the pile.

It should be mentioned that the yarns employed in weaving the back cloths are usually dyed black before being woven, but the mohair yarn is in its natural white state; after being trimmed, they are dyed of a yellowish brown colour, to get the tint of the lower parts of the hairs, and afterwards they are placed on a flat bench and brushed over with a dark brown dye, or "tipped," as it is technically called. This gives the surface colour, which extends halfway down each fibre of the pile, so as to impart to it a fine rich lustrous brown colour in a state of rest, but if disturbed by blowing upon it, the yellow colour reveals itself at the root of the hairs. These artificial seal skins are now brought to such a state of perfection, that some of the highest qualities fetch from thirty to forty shillings per yard wholesale.

Astracans are woven in the same way, but the pile-yarn is first twisted in the same manner as horsehair when intended for stuffing purposes. This yarn, after being twisted, is steamed, and made to retain the twist by heat. This twisted yarn is raised and cut in the same manner as de-

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scribed in the seal skin process. When the surface threads are cut through, they instantly curl up, so as to produce, when dyed black, the most exact resemblance to the minute curly locks of the Astracan sheep and lambs.

Dog skins are also woven much the same as the two former, but the pile-yarn is coarser. When cut, finished, and dyed, the piece is hung up lengthwise, and a needle, threaded with thin string, is run through from side to side, drawing it up so as to gather the whole web of cloth into narrow longitudinal folds. In this state it is steamed and passed between rollers in the most crumpled manner possible. This gives the peculiar appearance of irregularly pressed tufts of hair, so characteristic of the black Newfoundland dogs.

Chinchillas. These ingenious and interesting imitations have only been manufactured by one firm, Messrs Norton Bros. & Co. They are made exactly like seal skins, but are differently dyed. They have the lower part of the fibres of the pile a dark slate colour, the middle portion white, and the tips dark grey. This variation is not easily produced, and requires skill as well as care; first, the pile is brushed over with a liquid resist which covers about two-thirds of the fibres, but does not go down to the roots. It is then dipped into the colour which affects only the unprotected parts of the pile, that corresponding to the roots of the fur hairs, then the resist is removed chemically, and the pile, being brushed down, is slightly tipped with colour, so that it is then coloured at the base and tip, but not in the middle part, and has a fair resemblance to the beautiful fur of the chinchilla.

A long pile of fine white mohair has a very close resemblance to Polar bear skin, and some of these cloths, probably from this circumstance, are called "polarians."

A singular improvement has very recently taken place in the revolving furnace only lately introduced in our alkali manufactures, showing how soon apparent perfection is proved to be imperfect. In these furnaces it was at first found necessary to build internal piers of brick in order to keep the material from accumulating too much in one part,

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and it was thought that two and a half revolutions per minute was also a necessary velocity to ensure that result in combination with the internal piers. It is now found that by causing the cylindrical furnace to revolve six times per minute the same results are produced in less time without the inconvenience and wear and tear produced by the ponderous internal brick piers.

I cannot close this brief and very imperfect sketch of the many manufacturing improvements which have lately come under my own observation without alluding to two in our own neighbourhood. First, to the new method of preparing wheat for grinding by first disintegrating it, as may be seen at the mills of Messrs Walker & Gibson, at Bonnington, and which, although an application of an invention for a totally different and inferior purpose, owes to that enterprising firm its adaptation to the grinding of corn into flour; and last, but not least, the great invention of our President, which has within the last few months been recognised by almost every civilised country in the world as an invention of the greatest value, and likely in time, if not to rival railways, at least to be only second to them in promoting land transport—I mean, of course, the Road Steamer, of which this Society has reason to feel some pride as the production of one of its most honoured members.

On a New Method of Fixing Tubes in Vertical Boilers. By R. W. Thomson, C.E., F.R.S.E.*

Manufacturers and others who, on account of limited space and other reasons, use vertical boilers, have found that one of the greatest objections to them is the difficulty of keeping the tubes tight; all multitubular boilers are liable to have leaky tubes, for reasons which I will hereafter explain; but horizontal boilers do not give much trouble, as both ends of the tubes being under water, any small leaks "take up," as the deposit is forced into them. In vertical boilers, however, whenever a leak occurs at the upper end of a tube, it

* Read before the Society, 27th February 1871, and awarded the Society's silver medal, value five sovereigns.

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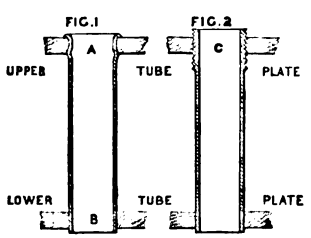
gets worse and worse, as no deposit can reach it, and causes great waste of fuel, and necessitates the stopping of the engine, in order to tighten the tube with a drift, or expander, or otherwise. The principal reason why tubes leak is their unequal expansion and contraction. Stays maintain the temperature of the water; but the tubes, through which alternately flame or heated air only is passing, are ever varying their temperature, and consequently their length. And this expansion and contraction follows no rule; a tongue of flame may shoot up one tube, which instantly lengthens to a much greater extent than the tubes on all sides of it. This expansion and contraction being admitted, it follows that we must humour it, and still find out some means of keeping the tubes tight; and, as I have shown above, it is necessary that the upper ends, in vertical boilers, should be kept perfectly tight, it follows that the upper ends must be perfectly and firmly fixed in the top plate, whilst a certain amount of play is allowed through the lower tube-plate. This is accomplished in the most perfect way as follows:—After the boiler has been put together, the holes in the top plate, and lower tube-plate, but most particularly the latter, are carefully rimled out parallel, by a rimer which passes through both plates; each tube has its lower end turned in the lathe to a good tight fit in its hole in the tube-plate; the tubes are then inserted in their places, and the upper ends firmly fastened by being expanded within and without the top plate, as shown in the diagram at A. (fig. 1). The lower end is left as it is; care should be taken that it is not turned over the tube-plate in any way, but be kept perfectly cylindrical, as at B. It then acts in the same way as the piston-rod of a steam engine working through a gland, the deposit acting as packing, which, although it may be constantly passing through, is always renewing itself. Some boilers so fitted by Roby and Co., have stood a water pressure of 300 lbs. on the square inch without leaking. Another way is to screw



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the upper ends of the tubes into the top plate, as at C. (fig. 2). A simple way of fitting the lower ends of the tubes, is to expand them slightly with a Dudgeon's parallel tube expander, instead of turning them to a perfect fit.

In the form of vertical boiler known as the "*pot*," the pot and lower ends of the tubes act so effectually in abstracting the heat from the ascending gases, that the tubes last for a very long time, as witness the specimen shown, which has been drawn out of a boiler after having been in constant use for eight months. From the way in which it stands bending and hammering, and from the fracture, it can be seen that the fibrous character of the iron is unaffected, although only one-half of it was covered with water.

The principle on which my method of fixing tubes rests, may be shortly stated thus :—It is impossible to fix tubes at both ends; any tendency to leak under water constantly cures itself, while a tendency to leak above water does not cure itself. It therefore follows that if the tubes are more firmly fixed at the top than they are at the bottom, the expansion and contraction will cause a slight movement of the tube in the lower tube-plate only, in which case no leak will take place.

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Address by the President, R. W. THOMSON, Esq., C.E., F.R.S.E., *concluding the Session* 1870–71, *delivered at the General Meeting of the Society, held on* 13*th November* 1871.

GENTLEMEN,—When elected two years ago President of this Society, I hoped to take leave of you at the termination of my period of office without that sense of duties unfulfilled which now oppresses me, and which renders it necessary that I should apologise to you for having so entirely failed in rendering those services which the Society has a right to expect from its President; but I am sure you will believe that nothing but an entire break-down in my health would have deterred me from discharging my functions to the best of my ability. I was for a long time a most assiduous attender at all your meetings, and received both pleasure and instruction from the papers and discussions which I had the advantage of hearing; and I trusted, when placed in the honourable position of President, to have made some efforts for the purpose of promoting the interests of the Society in a variety of ways; but I found exertions of this kind entirely beyond my strength, and I feel very keenly that I have lost a great satisfaction in being thus unable to make some return for all the benefits I have derived from my connection with the Society. But I am convinced you will, under the circumstances, excuse all my shortcomings in the past, and extend to the few observations I have to make in vacating the chair, all the indulgence due to one who can bring little more than good-will to the task of addressing you on the many important subjects that naturally offer themselves as fit for observation on

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an occasion like the present. It has been the custom —and a very good custom too—for your President to review in a short but comprehensive manner the great events specially connected with the mechanical arts, which have occurred during the previous year. It is not for want of abundant material that I abstain from giving you a history of the mechanical doings for the past two years, for during these two years there have been completed two of the greatest works ever achieved in this world, namely, the Suez Canal, and the Mont Cenis Tunnel. Both these works are destined to produce great effects on the intercourse of nations, and either is a subject sufficiently extensive to occupy the whole evening. The Suez Canal especially, apart from all the interesting details connected with its construction, has given an impetus to a change which was already making rapid strides, namely, the change from sailing to steam-ships for the transport both of passengers and goods. It is very curious to notice the way in which all progressive things are bound up together, for it is quite obvious that at the time the Suez Canal was commenced, steam navigation was not in a condition to compete with sailing ships in the carrying of freight on long voyages, and any attempt to use the canal for sailing ships would have been utterly absurd. The number of steam-ships passing through the canal even now is not enough to make it a paying concern, although doubtless in time it will become remunerative; but if the goods traffic had to be carried on by sailing ships, the canal would have never paid the cost of maintenance, for vessels would have sailed round the Cape of Good Hope in less time, and with more safety, than they could sail down the Red Sea. The Suez Canal has clearly come before its time, but it will un-

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doubtedly obtain a sufficient amount of traffic to keep it alive, and even to improve it, and finally to make it profitable. But if it had come twenty years earlier, the chances are that it would have been abandoned as a hopeless and ruinous undertaking. If, on the other hand, its execution had been postponed for another generation, and until steam-ships had more completely displaced sailing vessels, the shareholders would not then have had to wait so long as they will now do for a dividend. The world is full of enterprises of a perfectly rational and sound kind in every respect except one, namely, the date of their birth; and when an undertaking of the gigantic character of the Suez Canal is born before its proper time, and has to be supported through a long and perilous infancy, it is always a very risky and costly thing; but, unfortunately, it is impossible to bring colossal enterprises into existence just when they are wanted. They very often come too early, and then they are either left to die a natural death, or are preserved with much difficulty; but while these premature efforts are palpable enough to the whole world, the great undertakings which are postponed beyond the time when they ought to have made their appearance, cause as great or greater loss than the delays and disappointments attending all precocious undertakings. The wonderfully close connection and dependence of improvements on each other certainly help both to bring forward novelties required to complete the onward march of progress, and also to keep out of the ranks all schemes of too advanced a character to fit in with the particular period in which they first see the light.

With your permission I will depart from the old custom of giving an account of the past, and devote

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the very short time at my disposal to some guesses at what is yet to come. I need not say that the task of historian is a very much simpler one than that of prophet; nevertheless I think that we may be able to peer a little into the future if we carefully note the direction in which we have recently been travelling.

And first with regard to the amount of progress, especially progress in the mechanical arts, which is still open to us; I know that many persons consider that the steam-engine, gas, and telegraphs having been invented and made to work tolerably well, there is not much further to do; but this I think is a great mistake. It appears to me that greater changes are impending over the world during the next fifty years than have ever taken place in the centuries that have passed. These great changes may not be due to the discovery of new powers in nature. We may not invent anything corresponding to the telegraph, or the railway, or the steamship; but what we shall do is to apply these inventions to an extent which will completely metamorphose the whole globe. It is doubtless a source of deep and justifiable pride to have lived in a time when these great agents of civilisation were first brought into being, but their real results will only be apparent in the somewhat distant future, when they have all been applied, as they will be, to an extent and with an universality which very few persons are able to imagine. It is in the *wide application* of inventions that their importance lies. The mechanical developments now going on throughout the world are but the beginning of a marvellous transformation bearing a curious analogy to the progress which has apparently taken place in the animal creation. In the lower forms of life we find creatures having no particular circulation or nervous

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organisation—having, in fact, no special organs, no accumulation of brain in one part or muscle in another, but composed of mere matter aggregated into a mass. As we proceed up in the scale we find nervous matter assuming distinct form, circulation setting up, and a division of the mass into separate organs, all provided with a wonderful system of communication for carrying on the transfer of matter from one organ to another, and also with a nervous system which keeps up a sort of telegraphic correspondence between all the different organs, and exercises a general control over the whole body. A country unprovided with roads, telegraphs, and means of communication, can only be likened to the lowest forms of animal life. Almost every individual must work for himself, and perform in such manner as he is able a vast number of functions which, under a more highly organised system of communication, would be allotted to different members of the community. A human being representing the highest form of animal development differs from the worm, which is little else than an aggregate of rings connected together but able to live independently of each other. The material world of the future, as compared with the world of the past, is undergoing a change which, by a stretch of the imagination, may be compared to the difference between a human being and a worm. This great change will be due essentially to establishing in the material world channels of communication, consisting of railways, steam-ships, and other mechanical modes of conveyance, controlled and guided by a system of telegraphs. This circulation, so controlled and guided, will enable man to turn the material world to his benefit in a way utterly impossible and even inconceivable to popula-

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tions tied down to localities in the way the whole human race was before the advent of steam and electricity, as servants to men. In countries unprovided with steam communications, the population must all live close to where their food grows, but in the world of the future all this will be changed. Food, and all other products required for man's use, will be drawn from all parts of the earth at a constantly decreasing expenditure of labour in transport, thus admitting of great concentrations of men in localities where their labour can be turned to profitable account, and that without any considerable outlay in transferring from other parts of the earth whatever these dense populations may require, and again sending forth all the products of their labour with equally great economy.

It is clear that a great gain will arise, resembling in some sense the gain which results from a division of labour, when we have been able to set apart different portions of the earth for the purposes to which each is best adapted. There are many great tracts of country, especially in tropical regions, possessing the most marvellous fertility in the vegetable world, but by no means well suited for the rearing or permanent residence of human beings; and when our means of transport are such that man may live in climates that suit him best, and can still avail, by means of a perfect system of transport, of all the productions of other lands, we shall then have enlisted Nature herself in favour of the division of labour.

Here in the rugged north we can grow men of such brains and energy as the languid tropics can never produce. In the times to come these men will be constantly carrying their strength and fresh vitality to the most fertile regions, and after inaugurating development

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there, and introducing mechanical appliances which will permit of much work being done with the smallest expenditure of manual toil, they will return to their own countries again, where will soon be brought to them the fruits of what their intellects and skill have created in those distant climes, while in their homes they busy themselves anew with devising new levers wherewith to move the world further in the direction of economy and progress.

Patent Laws.

The conflict of opinion on this question shows clearly its remarkable difficulty. We find that evidence given before a Select Committee during the past session brought out the most extraordinary diversity of views amongst a great many witnesses of the greatest ability, and many of them entirely free from the disturbing element of self-interest. In fact, a list could be made out of names so eminent in favour of the principle of the patent law, that it will appear to be of overwhelming weight until the list of witnesses on the other side has been looked at and found to be almost equally strong. It appears to me that many persons fall into error in trying to form a just opinion upon this subject from regarding an invention as an *idea*. But the real fact is, that in almost all cases an invention protected by patent is as little an idea as a field of turnips is. The mere idea of the invention requires to be put into a practical form, and none but inventors know how much labour is involved in doing this. The truth is, that hardly any inventions of the least importance are workable as they spring from the brain of the inventor. They need to be modified, and altered, and amended under the guidance of practical experience

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and the pressure of practical difficulties. The protection given by patent has no other sound defence than the fact that it protects the labourer in enjoying the results of his labours. All who are acquainted with the history of the patent laws know that enormous outlays have often to be made in order to ascertain the value of the patent and to improve it, for it rarely indeed happens that any patent is workable in its first crude state. It is within my own knowledge, that almost every important invention has involved a large outlay, which never would have been made unless under the expectation of its being reimbursed from future profits. It is possible that in some chemical discoveries patents may have been granted of great value, of which the money outlay may not have been very large; but in all mechanical patents the outlay almost invariably is something incredible; and an inventor would no more expend his money nor the money of other people in perfecting an invention which any one might appropriate without his leave, than he would plant a field of potatoes which any man might dig up without his permission. It is hopeless to look for any principle on which a patent law could be founded. There is no other guide except an enlightened expediency. We sometimes fancy that the idea of property is a natural law almost as fixed in the human mind as the law of gravitation is in the material world; but there is no sound reason for believing the ordinary idea of property is anything more than a budget of compromises and expediency. But all ordinary kinds of property are of such an ancient order that we have, as it were, got them in our blood. There cannot, however, be a doubt that the ideas of property have vastly changed in times past, and are destined to

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still greater changes in the not very distant future. These old ideas of property have been tumbled about until they have worn themselves smooth, and fit in together pretty well. They have all grown up slowly and with the sturdiness which slow growth generally confers; but new comers, in the shape of fresh forms of property, are apt to be supposed of ricketty constitution, and to need a good deal of guidance and guardianship. Therefore the creation of a new species of property by the patent law has been attended with a good deal of agitation and concern. Something of its want of success may be due to the evil stock on which the idea was grafted, for the whole system of patent law has grown out of the king's power in former days to grant what were called monopolies, which meant, in fact, that the sovereign, unable to screw anything more out of his subjects, accorded to his favourite, whom he could not otherwise reward, a right to levy some sort of taxation for his private benefit. This right was limited by giving a power to tax some particular thing, but there was no pretence that the holder of the monopoly conferred any return whatever for the black mail which he levied. This evil beginning of the patent laws has to a certain extent tainted their whole course ever since, and they are now in such a state, that many of our most courageous legislators have declared that they were past all amending, and in despair cry out for their abolition. But there is, I think, little chance of the patent laws being abolished, however great the task and great the need for their reformation. It is rather curious to notice, that many of the arguments brought against the existence of the patent laws apply with still greater force to the possession of any kind of property by persons who

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do not make a good use of it. In fact, there are many reasons which could be urged on behalf of the existence of patents which would apparently make a stronger case for them than the defenders of ordinary property could make out on behalf of land and many other forms of material wealth. Nearly all the witnesses who have been examined before the Select Committee acknowledged the claims of inventors, even while they objected to the existence of a patent law. In fact, this law is objected to more from the difficulty of making it work well, than from any unwillingness to grant patents. These difficulties and obstacles to the well-working of a patent law are in many cases inherent in all laws under which property is held by the individual. Foolish and incapable holders of property of all kinds will use it to their own injury and to the damage of the community, very much as foolish patentees do their patents; and as long as we maintain a right of property when held by persons who are neither wise nor patriotic, there seems no reason whatever why we should abolish the patent laws because some patents, like some bits of property, are misused and turned to public detriment, and to the injury of their holders.

It has been proposed by some of the most conspicuous and active opponents of the patent laws to substitute a system of rewards for inventions. Now, any wilder scheme than this it is impossible to conceive. These rewards are to be conferred by a scientific tribunal. But any man acquainted in the least degree with the history of inventions can imagine what would be the fate of a scheme brought before a scientific commission. There is not one invention in a hundred the value of which can be ascertained until it has been put into extensive use. There is hardly a

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single important invention that I can recall to mind which would have passed muster before any scientific tribunal of its day. Of course it would be very easy for a scientific tribunal sitting now to determine the value of inventions which have been in use for a number of years, but the task the commission would have to fulfil would be to judge of the value of an invention before it is developed. It is not difficult to ascertain the acquirements, and something about the faculties and abilities of a young man of twenty, by a competitive examination; but the scientific commission before which inventors would have to appear would have presented to them what is virtually a baby, and they would be called on to pronounce what its value will be after it is grown up. Now, this is a problem entirely beyond human capacity. Neither inventors nor the most impartial scientific judges can form, except in very rare cases, any correct idea of the value of an invention. The way in which many of the most valuable inventions have changed hands for the merest trifle shows that even those best acquainted with the particular object of the inventor's scheme were quite unable to appreciate its worth. If tailors and mechanical engineers could not discern the importance of the sewing-machine, which not only brought its inventor in the end an enormous fortune, but which has effected one of the widest spread, though most unobtrusive revolutions, how with such evidence of lack of discrimination on the part even of those whose wits are sharpened by self-interest, can it be expected that a tribunal which is to judge of every invention under the sun should form any sound opinion whatever? I hold that any attempt to judge of the value of inventions in their infancy can only result in endless blunders, disastrous

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alike to the inventor and the community. If the inventor is simply to *register* his invention and send it out into the world, letting all who wish bring it into use and work what improvements they please upon it, postponing the reward to the inventor until time has been given to ascertain the value of his invention, then the difficulty arises which, to all practical men acquainted with the growth and change which all inventions undergo, is at once evident, how would it be possible to ascertain how much is due to the original inventor, and how much to those who have added successive improvements, and, in fact, turned what is very often a crude idea into a successful invention? Any attempt to work this latter system of registering inventions, and waiting for their development before the reward is fixed, would inevitably result in a rush to the registration office of all imaginative persons with undigested and crude ideas on every conceivable subject; and then would arise an amount of litigation and inquiry about the natural growth of the invention which would beggar altogether the difficulties and absurdities of the present patent law. It is very easy to see the obstacles which stand in the way of a well-working patent law, and no scheme whatever will be free from defects and blemishes any more than the laws relating to other kinds of property. What actually happens when an inventor desires to secure a right of property in an invention may be described as follows:—He presents himself to the community, and states that he has made an expedition into the Unknown, and has returned after having made certain discoveries therein; and the community—on condition, firstly, of his describing these discoveries accurately, and setting to work to cultivate, as it were, the lands he has discovered—grants to him a

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right of property therein. Now, there can be no doubt that if this programme were carried out in a reasonable way, many of the abuses of the patent law would dis appear, and it could be found whether an inventor, who presents himself at the proper office with a description of the discoveries in these unknown countries from whence he has returned, was merely describing a locality evidently identical with that for which a title had been granted to some previous explorer. This can only be prevented by a careful comparison between the specifications offered by inventors to the patent officials. We find, however, that no attempt is made to avoid granting rights to the same piece of property over and over again to different applicants. It is, by the very nature of things, impossible to procure a detailed map of this unknown country, otherwise the patent office could very easily refer to such map, and not only would they by its help be able to register the granting of different portions of it to different applicants, but they would further be able to ascertain whether the claimant for a patent had really made the discoveries, or whether others had been before him. The fact is, we can only become acquainted with this unknown country by putting together in the best way we can the fragmentary maps and descriptions furnished by persons who claim to have made explorations therein; and all that a patent tribunal, however learned or able, could possibly accomplish, would be to guard against issuing titles to discoveries claimed in succession by different persons. Whether these discoveries are actual and real facts, or mere dreams, no body of men can possibly ascertain. All that any patent tribunal could do would be to guard against the issuing of grants twice over for the same discovery. Even this would be an enormous

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improvement upon the existing system under which patents are granted for the same thing over and over again, as long as applicants are willing to pay the fees. What I would propose would be the erection of a patent tribunal composed of scientific men, whose duty it would be to examine all applications for patents; and on this tribunal would be thrown the task of ascertaining whether the invention for which a patent was applied had been anticipated by any previous patentee, or whether it was in use already without being patented. As soon as the petition for a patent was lodged, along with a description of the invention, this inquiry would be made, and the result communicated to the applicant for a patent.

I would then leave the entire responsibility of taking any further steps to the applicant. By this means, there is no doubt whatever that an immense number of patents would never go beyond this first stage. It would not, I think, be a safe or wise proceeding to intrust the power of refusing patents to any tribunal whatever. It would, I think, be found a far safer course to trust to the discretion of an intending patentee, after receiving the information I have indicated from the Commissioners, to go on at his own risk; because I think it more likely that, having all the information the Commissioners possess, he would be a better judge of the expediency of proceeding with his application than they could possibly be, because he is by this mode of proceeding placed in possession of all that the Commissioners know on the subject, and has in addition his special knowledge of his own invention. I would throw this task of inquiring what has been done in connection with any invention, before granting a patent for it, on the patent Commissioners, simply

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because for the mere purpose of inquiry they could do it with an economy and certainty greatly exceeding what could be accomplished by the efforts of intending patentees. A set of men accustomed to inquiries of this kind, and familiar with the past history of patents and inventions, could, with very little trouble indeed, place every intending patentee in complete possession of all that has been done before his time. Of course, the cost of this inquiry would be paid by a sufficient fee from the intending patentee; and I am quite confident that a mere tithe of the enormous fees now exacted from inventors who apply for patents, would suffice to make these inquiries in the most thorough manner, and thereby save an enormous amount of useless labour in attempting to carry out inventions which have been anticipated, and are therefore not patentable, and inventions which have been tested and found to be valueless. These inquiry Commissioners ought to have no power whatever to refuse patents, or of pronouncing any opinion upon their validity. No doubt many disputes as to the validity of patents would arise, even after the diminution of numbers which would inevitably follow the intimating to the patentees the results of the preliminary inquiries, for a great many inventors would find it useless to take any further steps, and a great many others would be enabled before sending in their final specification, to so curtail and modify their schemes as to bring them within the limits under which a valid patent could exist. A great many existing patents are endangered and very often broken down by claiming small portions of things either not new or which belong to some other patent; and there is no doubt that all these dangers and difficulties could be almost entirely avoided by the preliminary inquiries

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which I have indicated. It is, I believe, beyond human power to contrive a tribunal capable of settling litigations on patents satisfactorily under any statute law; and I do not know that anything much better than the present system of trial before a jury could be contrived for the settlement of litigated cases. But very much might be done by the mode I have suggested of lessening the risk of litigation by preliminary inquiry, thus rendering patents very much less numerous and very much safer.

Some people have proposed that no patents should be granted to inventors, and that they should be allowed no title of property in their inventions. Why, they say, should a man found a claim on an idea? No man can found a claim on an idea as long as he keeps it to himself, but if he gives expression to it, and such expression is pleasant or profitable to others, he generally receives some remuneration for it. He may express his idea in painting, or music, or poetry; but if it is worth anything to others, they will not require him to give it them for nothing. Yet the advocates of free inventions suggest that the inventor shall publish his idea to the world, with the understanding that he is to have no more right in it than any one else, and that any who likes may seize it. "Look," they say, "what an impetus would be given to the progress of the country, if, instead of allowing an individual to hold on for a time to his invention, it were to belong at once to all, and all might make use of it —without paying for it!" But they have omitted one or two things in their scheme. It is probable that not so many discoveries would be made if the discoverers knew beforehand they were to have no ownership in them. On the other hand, the mass of "ideas"

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that would be presented to the public gratis would be so enormous, that the chances of detecting the grain of wheat in the bushel of chaff would be poor indeed. Then, again, how little would come, not only of offering, but of pressing the most valuable ideas upon the public, can be judged from the way in which the announcement of any discovery still in embryo is received now. If a man makes it known that he is busied in giving shape to a new idea, in which he has such trust that he is expending on it his labour and his means, he may be sure that he will have to encounter a considerable amount of ridicule and incredulity. So that, even with the example of an earnest believer before them, the world will not accept a new idea till it is clothed in a material form, and commands conviction through the testimony of their senses. Since, then, we find that unembodied ideas meet with so little recognition, we must infer that the community will derive most advantage by inducing the inventor and his idea to keep together. He alone will have faith enough in it, devotion enough to it, understanding enough of it, passion enough for it, to give to it his toil by day and his thoughts by night—to sacrifice for it his rest, his strength, and perhaps all he possesses. In one word, he alone will give up his life to it that it may live. It may be that all his efforts, all his expectations, all his struggles, and all his hopes, may end in disappointment, or he may at last see his creation go forth in the full glory of vitality, efficiency, and completeness. In the event of his success the gain to the world is incalculable, for each new power produced gives rise to a never ending progress. If then we would encourage and justify inventors in such strenuous exertions to foster, mature, and incorporate their

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ideas, we must surely allow them to count for a little while their own what it has cost them so dear to achieve.

Sewage and Water Supply of Large Towns.

Nearly a quarter of a century ago, I devoted considerable time to investigating the question of sewage of large towns, and the conviction was forced upon me, that the system which was then being constantly extended—that is to say, the mixing up sewage and drainage—would lead us into infinite trouble. I came to the conclusion that the only principle on which sewage and drainage could be carried out was by complete *separation* of the two things, which are essentially incompatible; and I accordingly wrote some articles, I believe in 1848, in a newspaper then of great influence,—namely, the *Morning Chronicle*,—advocating the separation of drainage from sewage. I speedily, however, saw that this idea, whether well or ill founded, was too far in advance of the times to be seriously entertained, and I thereupon ceased to occupy myself further with the matter. I have watched, however, the progress of these questions ever since the date I have mentioned, and I am more convinced than ever, that the only true solution of the difficulties now surrounding these questions is the complete separation of sewage from drainage. The constantly increasing quantity of water used in large towns brings about the result, that the fluid flowing through the common sewers contains so much water, and so little manure, that any attempt to carry it to a distance, or to deal with it so as to extract the valuable manure from the enormous quantity of water with which it is mixed, cannot economically be carried out. When it is borne

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in mind that in a town like Glasgow the daily manurial contribution of each inhabitant is mixed with about 500 lbs. of water, to say nothing of the addition made by rain-water, and the cost of distributing this sewage fluid over a sufficient extent of land will be as much as collecting the water, and bringing it into the houses, it may be roughly assumed that the cost of distributing the sewage over the lands will equal that of bringing the water into the towns. In fact, the dilution of sewage is now so great as to render it utterly valueless, and to make it a horrible incumbrance. But if the sewage matter had a system of pipes and channels of its own, it would then be preserved in such a concentrated form that we could afford to collect it, and carry it to a distance, and to deal with it as a valuable manure. But as long as we persist in mixing one or two lbs. of manure with several hundred lbs. of water, we must be contented with such applications as we find in the neighbourhood of Edinburgh, where a very small portion of the sewage can be used, without any outlay on the part of those benefiting by its use, for the purpose of growing grass for consumption in towns. Now, as the consumption of grass in towns is so limited that it cannot possibly admit of more than a mere fraction of the sewage being used for its production, and as the sewage, in its very bulky and diluted state, cannot be carried to a distance, nor can the grass which it is to produce be carried back from distant localities, it follows that any extension of the Edinburgh system is quite hopeless. A careful consideration of the subject in all its bearings has led me to the firm conviction that large towns will ultimately be compelled to separate entirely their system of sewage from their ordinary

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drainage. This separation they will be driven to by the double reason of the great difficulty of dealing in any manner whatever with the enormous quantity of thin sewage matter—so thin, indeed, as to be very valueless as manure, and yet in quantity so large as to be extremely unmanageable; and, on the other hand, the desire to preserve in a profitable form the great quantities of manure produced in towns. It is almost certain that these two reasons, acting in conjunction, will by-and-by bring about a complete change in our present system.

The difficulty of carrying out this separation is far less than at first appears. The separation of sewage from drainage would involve some re-arrangments in the pipes within the houses, as well as a separate set of channels under the streets. The cost of such channels under the streets would be comparatively small, as the matter flowing through them would be almost constant in quantity, whereas the drains, having to provide for rain-storms, must be of enormous capacity. My proposal, and the system I would suggest, would simply consist in devoting the existing sewers under the streets to the purpose of drainage, while I would lay down cast-iron pipes for the purpose of conveying sewage matter into proper receptacles, which would be entirely closed so as to prevent the escape of all deleterious gases, such as takes place when sewage matter is thrown into the great sewers. It is found to be quite impossible to prevent the escape of all kinds of noxious gases through gully holes, gratings, and openings of all descriptions in the existing sewers.

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Water Supply.

Closely connected with the suggestion which I have just mentioned regarding the separation of sewage from drainage, is another suggestion which I venture to make, namely, the separation of our water supply into two qualities. The constant tendency of the increasing population to gather together in large towns, combined with the continually increasing consumption of water for each inhabitant of these towns—an increase, it must be borne in mind, not of water to drink or to use in any form of cooking, but an increase in the use of water for watering the streets, for bathing and general sanitary purposes—renders it necessary to provide such an enormous quantity of water, that it has become practically impossible in many large towns to procure it without lowering the standard of the quality. Water of sufficient purity for washing clothes, bathing, watering the streets, manufacturing purposes, water-closets, and a number of other purposes, could be procured in almost all localities with very little trouble and at very little cost; but when our municipal authorities set to work to water the streets and to flush the sewers with water of the same quality as we require for drinking, then the task indeed becomes a very difficult one, and the attempt to carry it out an absurd waste of money and energy. If we take a town like London, with a population nearly equal to that of all Scotland, it will be readily granted that a supply of fifty gallons a-head, or even half this quantity of water, so pure that chemists fight over the question as to whether it contains some fraction of a grain more or less of some substance good or bad, is physically impossible. If a proper system of separation

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of the sewage from the drainage of the towns lying above London in the valley of the Thames were carried out, so that the manurial products of the population were retained for use on the lands surrounding the various towns and villages, and only rain-water, springs, and comparatively clean water flowing from baths and other domestic sources were allowed to flow into the river, the water in the Thames would be sufficiently pure to allow an unlimited quantity to be pumped up as it passes through London to supply water suitable for all sanitary and domestic purposes (except drinking and cooking food), as well as for manufacturing purposes, and for watering the streets, supplying fountains, and, in fact, for any purpose and to any extent that might be required. The water supply of Edinburgh has unfortunately drifted into a position sufficient to deter an engineer who does not happen to be a politician from meddling with it at all. I will say nothing further on the subject than this, that it appears to me that Edinburgh has a singularly favourable opportunity for carrying out the suggestion I have made for the supply of potable water, apart from water required for all other purposes. We happen to have the Crawley springs, sufficient to supply many times over all that could possibly be required for potable use, not only at present, but for many generations to come; and what I would suggest as worthy of consideration, would be the laying down of separate and comparatively small pipes from the Crawley springs through all parts of Edinburgh, each house being provided with a tap for the purpose of supplying this pure water, and that without the intervention of any cistern or contrivance of that kind. There would be no difficulty whatever in keeping up a constant supply of this pure spring

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water. The existing pipes might remain precisely as they are for the supply of water-closets, baths, and so on, and the Crawley spring would simply be drawn upon as far as might be required for potable use, which probably would not amount to a thirtieth part of the total quantity of water now sent into Edinburgh. The surplus of the Crawley spring would flow into the existing pipes, along with the largely increased supply which could be very easily obtained from the Pentland Hills, and that without any great trouble and cost, provided we can accept of a lower quality of water; and in this there would be no hardship, because it is perfectly clear that water faintly coloured with peat, or otherwise falling short of the purity of the Crawley spring, would still be sufficiently pure for all purposes for which it might be used. This separation of water into two qualities will, I believe, get rid of enormous difficulties in the supplying of water to large towns, and it offers a solution of the question which has agitated Edinburgh so much and so unprofitably.

Steam in Agriculture.

There are many theoretical reasons for believing that steam will produce as great a revolution in agriculture as it has done in manufacturing industry, and there are even some signs that this change has commenced; but the progress hitherto made has given no token of the greatness of the revolution which, I think, will soon be in full swing. Not only will steam displace horses and cattle, but it will perform work in agriculture never dreamt of as possible of accomplishment by means of horses or oxen. It is not only that all the existing operations will be effected in a much more economical manner by means of steam than they now are by

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means of animal power, but we shall extend to our fields the fertility now achieved in our gardens; for we shall, by means of steam power, be able to transport soils, and bestow upon our fields the great amount of labour which we can now only afford to give to market gardens in the neighbourhood of large towns. Hitherto we have been content to accept of such soils as nature has by accident scattered about over the surface of the earth. Clay soils and sandy soils, as well as light soils and heavy soils, we find distributed over the land in the most irregular and capricious manner. These soils have had their positions assigned them, as it were, by the joint action of water and atmospheric influences, and of course have not been arranged with any view to man's requirements; but owing to the vast labour involved in transporting on any great scale sand to mix with clay soil, or clay to mix with sandy soil, any serious attempt to amend the accidental distribution of soil, it is beyond our power so long as we employ merely the force of animals to effect this transportation. We find throughout the land a most extraordinary difference in fertility, depending upon the composition of the soil; and we hardly ever think of, and still less rarely attempt, making any improvement on what we find laid out for us by nature. But there is every reason to believe that we shall gradually effect such changes in the composition of the soil throughout all lands capable of being cultivated, as will ensure to us crops undreamt of in the present day; and this will be effected by transporting from one place to another what experience has told us is required to transform every field into that kind of soil which we know is best adapted for growing the crops we require.

There are many other subjects which I should have

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liked, had time permitted, to have commented upon; but the length to which my remarks have already extended precludes my even alluding to them. And, in conclusion, I again express to you the great regret I feel at having been able to do so little for the Society, and ask you to believe that nothing but absolute inability would have deterred me from doing my work in a more complete manner.

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On the Relative Photogenic or Illuminating Value of Vegetable, Animal, and Mineral Oils, and Coal Gas. By STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry.*

The communication which I have now the pleasure of bringing before the Society, has special reference to the light-giving power and relative cost of the illuminating agents in common use, and will include the results of a large number of experiments made upon the subject during the last ten years. Considering, however, that great fluctuations occur from time to time in the quality and cost of materials, I have repeated every experiment during the last few months, and have made great additions thereto.

The observations included common dip or tallow, composite, and paraffin candles; sperm, rape, and whale oils; paraffin and petroleum oils; and coal gas.

The illuminating standard of intensity of light was the sperm candle, burning 120 grains per hour; and the relative photogenic power of the flames, as contrasted with the said candle, was determined by Bunsen's photometer. The sperm candles were of the best quality, and burned generally between 120 and 122 grains per hour, and in no case was the trial considered as conclusive where the standard candle burned more than 125 or less than 117 grains per hour. The candle was weighed immediately before and after each experiment, and the requisite calculations were made to bring the light to the standard of 120 grains per hour. The room in which the experiments were conducted was kept at an uniform temperature of 60° F.

Considering that the various illuminating agents employed in these trials were of such different qualities and natures as candles, oils, and gas, sold and purchased respectively by the pound, gallon, and 1000 cubic feet, it appeared desirable, after determining the illuminating or photogenic

* Read before the Society, and illustrated by diagrams and experiments, on 27th November 1871.

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power according to the pound, gallon, or cubic feet, that the light evolved in each case should be calculated into its equivalent in lbs. of sperm. Such a plan of recording the results enables the observer to see more clearly the relative illuminating power of the candles, oils, and gas. And, lastly, the photometric results were contrasted by calculating the light-giving value of each source of light yielded for a given price—say, a pennyworth of the material. In making the calculations, it was necessary to fix on a unit, and it was found best to take the standard sperm candle for one hour as *the unit of a candle hour*, and to reckon any light as equal to a given number of candle hours for 1d., indicating that the light evolved was equivalent to that given by a standard sperm candle for the stated period.

Common Tallow or Dip Candles.—Three sizes of these candles were experimented upon, viz., 6, 8, and 12 to the lb., and the price was 6d. per lb., so that the respective candles cost 1d., ¾d., and ½d. each. The average weights of the candles were 1118, 849, and 611 grains each. The size of the wicks was about the same in each sort, and, when burning, the candles lost in 1½ hours:—

1st, or largest size, 299 grains,
2d, or medium „ 297 „
3d, or smallest „ 300 „
} and { giving an average of close upon 200 grains per hour.

The consumpt of tallow, therefore, in each size of candle was practically the same, and the illuminating value of the light evolved from each was equal to 1·25 standard sperm candles burning during the hour. Calculating that if 200 grains of tallow consumed during the hour were equal to 1·25 candle or 150 grains of sperm burned during the same period, what would 1 lb. of the tallow candles be equal to? The following results were obtained:—

200 : 7000 : : 150 : : 5250 grains of sperm;

or 1 lb. of tallow, consumed in common dip candles, evolves a light equal to that capable of being obtained from 75 lbs. of sperm, burned in standard sperm candles of 120 grains per hour.

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Composite Candles.—These candles were obtained in three sizes, viz., 4, 6, and 8 to the lb., and respectively weighing 1758, 1165, and 851 grains each on the average. The price was 8d. per lb., so that each candle cost respectively 2d., 1½d., and 1d. During burning for 1½ hours, the loss in weight was as follows:—

1st, or largest size,	260 grains	Average consumpt per hour, 154 grains.
2d, or medium „	232 „	
3d, or smallest „	199 „	

The light evolved during the combustion of the composite candles was in accordance with the relative consumpt, and the average illuminating power was equal to 1·1 standard sperm candle, or 132 grain of sperm. Calculating these figures into 1 lb. of composite candles, and its equivalent in sperm, we obtain the following results:—

154 : 7000 : : 132 : : 6000 grains of sperm ;

or 1 lb. of composite candles yields a light which is equivalent to that evolved from ·85 lb. of sperm consumed in standard sperm candles.

Paraffin Candles.—These candles were also in three sizes, viz., 6, 8, and 12 to the lb., and cost 1s. per lb., so that the price of each candle was respectively 2d., 1½d., and 1d., whilst the average weight of each size was 1117, 848, and 567 grains. The loss in weight during 1½ hours consumpt was as follows:—

1st, or largest size,	215 grains	Being an average consumpt of 137 grains per hour.
2d, or medium „	206 „	
3d, or smallest „	195 „	

The light evolved during the combustion of these candles was greater than that given by the tallow and composite candles, being equal to 1·494 standard sperm candles, or 179·28 grains of sperm. This result, calculated into lbs. of paraffin and sperm, gives the following:—

137 : 7000 : : 179·28 : : 9160 grains of sperm ;

or 1 lb. of paraffin burned in candles evolves a light equal to that capable of being yielded by 1·3083 lbs. of sperm when consumed in standard sperm candles.*

* This amount of light yielded by solid paraffin in candles is theoretically much less than what ought to be obtained from the paraffin, and indicates

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These experimental results on the candles may be shortly stated thus:—

1 lb. of tallow candles	is equal in light-giving power to	·75 lb. of sperm candles.
1 lb. of composite „	„	·85 lb. of „ „
1 lb. of paraffin „	„	1·3083 lb. of „ „

Considering, however, the relative cost of the tallow, composite, and paraffin candles, it follows that, value for value, these results require to be amended according to the purchase price of the materials. A lb. or 7000 grains of the standard sperm candle, consuming 120 grains per hour, will necessarily give

120) 7000 (58·33 candle hours.

One lb. of tallow candles is equal to ·75 lb. of sperm, and costs 6d., hence—

1·00 : ·75 : : 58·33 : : 43·74 candle hours from 1 lb.

6d.) 43·74

7·29 candle hours for 1d.

One lb. of composite candles is equivalent to ·85 lb. of sperm, and costs 8d., therefore—

1·00 : ·85 : : 58·33 : : 49·58 candle hours from 1 lb.

8d.) 49·58

6·19 candle hours for 1d.

One lb. of paraffin candles, costing 1s., is equal to 1·3083 lb. of sperm, hence—

1·00 : 1·31 : : 58·33 : : 76·41 candle hours from 1 lb.

12d.) 76·41

6·36 candle hours for 1d.

Sperm, Rape, and Whale Oils.—These oils were burned in two kinds of lamps, viz., 1*st*, a common flat wick lamp, such as is used in kitchens and country cottages; and 2*d*, an inch Argand lamp with glass chimney, such as is employed in larger rooms. The oils were of excellent quality of their class, and cost at retail prices, sperm oil, 9s. per gallon; colza or rape oil, 5s. per gallon; and whale oil, 4s. per gallon.

Sperm Oil in Flat Wick Lamps.—The consumpt of oil in 10 hours was 4·12 oz., which gives ·412 oz. per hour; and the

that there is great room for improvement either in the manufacture or mode of combustion of these candles.

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average light evolved was equal to 1·306 of standard sperm candles, or 156·72 grains of sperm. Calculating these results into one gallon of the sperm oil, viz., 160 oz., the following results were obtained :—

·412 : 160·000 : : 156·72 : : 60861 grains of sperm ;

or one gallon of sperm oil, consumed in the flat wick lamp, is equal to 60861 grains (8·69 lbs.) of sperm candles burned each at the rate of 120 grains per hour.

Rape Oil in Flat Wick Lamps.—In 10 hours 3·90 oz. of oil were consumed, and this quantity is equal to ·39 oz. per hour. The light yielded was equal to 1·05 standard sperm candles, or 126 grains of sperm. Carrying on these calculations to the gallon of rape oil, we get as follows :—

·39 : 160·00 : : 126 : : 51693 grains of sperm ;

or one gallon of the rape oil, burned in the flat wick lamp, evolves a light equal to that yielded by 51693 grains (7·39 lbs.) of sperm consumed in standard sperm candles.

Whale Oil in Flat Wick Lamp.—This oil burned at the rate of 3·50 oz. in 10 hours, which gives the hourly consumpt as ·35 oz. The light was equal to ·9 standard sperm candles, or 108 grains of sperm, and calculating this into the gallon of oil,

·35 : 160·00 : : 108 : : 49371 grains of sperm ;

or one gallon of the whale oil, consumed in the flat wick lamp, is equal to 49371 grains (7·05 lbs.) of sperm burned in standard sperm candles.

Sperm Oil in Argand Lamps.—The quantity of oil consumed in the Argand lamps was 2·30 oz. per hour, being fully five times the amount capable of being burned in the flat wick lamp. The light evolved was equal to 13 standard sperm candles, or 1560 grains of sperm consumed during the hour. Calculating into the gallon of oil, the following results were obtained :—

2·3 : 160·0 : : 1560 : : 108522 grains, or 15·5 lbs. of sperm.

The great increase in light when the sperm oil is consumed in Argand lamps, as compared with that obtained

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when the same oil is burned in flat wick lamps is due to the greater body of oil which is consumed at the same time, and the consequent larger flame yielded by the oil, which enable the oil gas to resist more completely the deleterious effects of the oxygen of the air in intermingling with, and attenuating down, the luminosity of the flame. The practical result is, therefore, that the greater the body of oil which can be consumed in a lamp at one and the same time, the higher the illuminating power which is obtained from a given volume of the oil. The same observation applies to other oils, such as rape and whale oils. These remarks will explain why it is that a gallon of sperm oil, weighing less than 9 lbs., can evolve a light in the Argand lamp, which is equal to that given by 15½ lbs. of sperm burned in candles consuming each only 120 grains per hour. The sperm oil is burning at the rate of 2·3 oz., or 1006·25 grains per hour, whilst the standard candle is only consuming 120 grains, or slightly more than ¼ oz. of sperm per hour.

Rape Oil in Argand Lamps.—The consumpt of oil was 2·133 oz. per hour, and the light evolved was equal to 11·33 standard sperm candles, or 1360 grains, which, when calculated into the gallon of the oil, gave

2·133 : 160·000 :: 1360 : : 102016 grains, or 14·57 lbs. of sperm.

Whale Oil in Argand Lamps.—This oil burned at the rate of 1·95 oz. per hour, and yielded the light of 9·8 standard sperm candles, or 1176 grains of sperm, and the results, calculated for the gallon of whale oil, yielded

1·95 : 160·00 : : 1176 : : 96492 grains, or 12·69 lbs. of sperm.

The photogenic results of the combustion of the fatty oils in flat wick and Argand lamps may be contrasted as follows:—

Flat Wick Lamps.

1 gallon of sperm oil			is equal in light-giving power to	8·69 lbs. of sperm candles.			
1	„	rape	„	„	7·39	„	„	„
1	„	whale	„	„	7·05	„	„	„

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Argand Lamps.

1 gallon of sperm oil	} is equal in light- giving power to	}	15·5	lbs. of sperm candles.	
1 „ rape „	„		14·57	„	„ „
1 „ whale „	„		12·69	„	„ „

These results may be calculated for the price of oil as well as for the quantity consumed, and may, as in the case of the candles, be reduced to the common standard of candle units for 1d.

Flat Wick Lamps.

A gallon of sperm oil costs 9s., and evolves a light equal to 8·69 lbs. of sperm; and each lb. of sperm candles, burning at the standard rate of 120 grains per hour for each candle, gives 58·33 candle hours; consequently,

Sperm Oil at 9s. per gallon.

$$\frac{58{\cdot}33 \times 8{\cdot}69}{108} = 4{\cdot}69 \text{ candle hours for 1d.}$$

A gallon of rape oil = 7·39 lbs. of sperm candles; therefore,

Rape Oil at 5s. per gallon.

$$\frac{58{\cdot}33 \times 7{\cdot}39}{60} = 7{\cdot}18 \text{ candle hours for 1d.}$$

A gallon of whale oil = 7·05 lbs. of sperm candles; therefore,

Whale Oil at 4s. per gallon.

$$\frac{58{\cdot}33 \times 7{\cdot}05}{48} = 8{\cdot}56 \text{ candle hours for 1d.}$$

Argand Lamps.

A gallon of sperm oil = 15·5 lbs. of sperm candles; therefore,

Sperm Oil at 9s. per gallon.

$$\frac{58{\cdot}33 \times 15{\cdot}5}{108} \quad 8{\cdot}99 \text{ candle hours for 1d.}$$

A gallon of rape oil = 14·57 lbs. of sperm candles; therefore,

Rape Oil at 5s. per gallon.

$$\frac{58{\cdot}33 \times 14{\cdot}57}{60} = 14{\cdot}17 \text{ candle hours for 1d.}$$

A gallon of whale oil = 12·69 lbs. of sperm candles; therefore,

Whale Oil at 4s. per gallon.

$$\frac{58{\cdot}33 \times 12{\cdot}69}{48} = 15{\cdot}42 \text{ candle hours for 1d.}$$

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The following table will show at a glance the respective cost of the candles and the fatty oils, and the relative value of the light obtainable from a given price of each.

Tallow candles	gives a light	equal to	7·29	candle hours	for	1d.
Composite „	„	„	6·19	„	„	1d.
Paraffin „	„	„	6·36	„	„	1d.

Flat Wick Lamps.

Sperm oil	gives a light	equal to	4·69	candle hours	for	1d.
Rape „	„	„	7·18	„	„	1d.
Whale „	„	„	8·56	„	„	1d.

Argand Lamps.

Sperm oil	gives a light	equal to	8·99	candle hours	for	1d.
Rape „	„	„	14·17	„	„	1d.
Whale „	„	„	15·42	„	„	1d.

Paraffin Oil.—Five different lamps were employed in the experiments upon the illuminating power of paraffin oil, viz. :—

Small sized flat wick or cottage lamps.
Medium „ „ parlour lamps.
Large „ „ dining-room lamps.
Small Argand lamp with ¾-inch wick, and
Doty's Argand lamp with 1-inch wick.

The oils employed were manufactured by the Uphall Mineral Oil Co., and Young's Paraffin Oil Co., and were of excellent quality. The retail price was 2s. per gallon.

Small or Cottage Lamp.—The consumpt of oil in this lamp was ¾ oz. per hour, and the light evolved was equal to 6 standard sperm candles of 120 grains per hour, or 720 grains of sperm, which, calculated into the gallon of the paraffin oil, viz., 160 oz., gave the following results :—

·75 : 160·00 : : 720 : : 153600 grains, or 21·943 lbs. of sperm.

Medium or Parlour Lamp.—Consumed 1⅛ oz. of paraffin oil per hour, and yielded a light equal to 9 standard sperm candles, or 1080 grains of sperm ; consequently, the photogenic value of one gallon of the oil was,

1·125 : 160·000 : : 1080 : : 153600 grains, or 21·943 lbs. of sperm.

Large or Dining-room Lamp.—Burned 1½ oz. of paraffin oil per hour, with the illuminating value of 12 standard sperm candles, or 1440 grains of sperm, so that the gallon of oil was equal to

1·5 : 160·0 : : 1440 : : 153600 grains, or 21·943 lbs. of sperm.

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Small Argand Lamp.—Consumed 1⅛ oz. of paraffin oil every hour, and the illuminating power of the light evolved was equal to that obtained from 9 standard sperm candles, or 1080 grains of sperm, which, calculated into the gallon of oil, gave as follows:—

1·125 : 160·000 : : 1080 : : 153600 grains, or 21·943 lbs. of sperm.

Doty's Argand Lamp.—Burned a little more than 2 oz. (2·004) of paraffin oil per hour, and yielded a light equal to 19·83 standard sperm candles, or 2380 grains of sperm, which, when calculated for the gallon of oil, gave the following results:—

2·004 : 160·000 : : 2380 : : 190400 grains, or 27·2 lbs. of sperm.

The foregoing experimental observations demonstrate that the paraffin oil, when consumed in any of the flat wick lamps, or in the small Argand lamps, evolves the same amount of light from the gallon of the oil; and in this respect the paraffin oil differs materially from the vegetable and animal oils, which, as noticed previously, evolve proportionally more light when they are consumed in larger lamps, and in greater quantities at a time. On the other hand, the paraffin oil, when burned in the cottage lamp with a 6-candle power, yields as much light from the gallon as when consumed in larger lamps with a 9 or 12 candle power,—in other words, two 6-candle power paraffin lamps are equal in light-giving power to one 12-candle power lamp, and will consume exactly the same quantity of oil. The same remark applies to the small Argand lamp, which burns with a 9-candle power, and where for the consumpt of oil the light obtained from a given volume of the oil is neither greater nor less than what is yielded from any of the sizes of flat wick lamps. Employing, therefore, any of the common constructions or sizes of paraffin lamps, the oil evolves a light strictly proportionate to the amount of oil consumed at the time.

The Doty lamp, however, from the superiority of its construction, and the more perfect combustion of the oil, yields a higher photogenic value from the paraffin oil, in the

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proportion of 27½ lbs. of sperm to 22 lbs. obtained as equivalent of light in the more common lamps.

The experimental results yielded by paraffin oil may be more readily contrasted with those obtained from candles and the animal and vegetable oils, by reducing the light evolved to the common standard of candle units for 1d., and which was adopted in the previous parts of this paper. Thus—

A gallon of the paraffin oil consumed in the cottage, parlour, or dining-room flat wick lamps, or in the small Argand lamp, yields a light equal to that capable of being obtained from 21·943 lbs. of sperm burned in standard candles at the rate of 120 grains per hour; and as each lb. of sperm candles gives 58·33 candle hours or units, it follows that the ordinary lamps yield with

Paraffin Oil at 2s. per gallon.

$$\frac{58{\cdot}33 \times 21{\cdot}943}{24} = 53{\cdot}33 \text{ candle hours for 1d.;}$$

whilst if the paraffin oil is purchased at 1s. 6d. per gallon,

Paraffin Oil at 1s. 6d. per gallon.

$$\frac{58{\cdot}33 \times 21{\cdot}943}{18} = 71{\cdot}11 \text{ candle hours for 1d.}$$

When the results in the Doty lamps are worked out in the same way, it is found that—

Paraffin Oil at 2s. per gallon.

$$\frac{58{\cdot}33 \times 27{\cdot}2}{24} = 66{\cdot}10 \text{ candle hours for 1d.}$$

And when paraffin oil may be purchased at 1s. 6d. per gallon, the Doty results yield—

Paraffin Oil at 1s. 6d. per gallon.

$$\frac{58{\cdot}33 \times 27{\cdot}2}{18} = 88{\cdot}13 \text{ candle hours for 1d.}$$

The foregoing results show at once the great superiority and relative cheapness of paraffin oil as an illuminating agent over any vegetable or animal oils or fats consumed in candles or in lamps. The highest photogenic value obtainable from candles was from the common dip or tallow, which gave 7·29 candle hours for 1d., and the greatest illuminating power of the oils, considering the cost, was

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given by whale oil, which yielded 8·56 candle hours for 1d., when consumed in common lamps, and 15·42 candle hours for 1d., when burned in the best Argand lamps. With paraffin oil, however, even when consumed in the common flat wick lamps, there is a return of 53·33 candle hours for 1d.; and when burned in the Doty lamp, 66·10 candle hours for 1d.—the oil being taken at 2s. per gallon, or 71·11 candle hours for 1d., and 88·13 candle hours for 1d. when the oil is 1s. 6d. per gallon. But reckoning the paraffin oil at the higher price, there is a sudden passage from candles giving 7¼ candle hours for 1d., and fatty oils giving in common lamps 8½ candle hours for 1d., or in improved Argand lamps 15½ candle hours for 1d., to paraffin oil in common lamps yielding 53⅓ candle hours for 1d., and in Doty's improved lamp 66 candle hours for 1d. Paraffin oil, therefore, is from four to eight times cheaper as an illuminating agent than any of the candles or vegetable and animal oils employed for light-giving purposes.

Petroleum Oil.—Experiments were made with petroleum oil in the flat wick, Argand, and Doty lamps, and the results, taking cost into consideration, were on the average one-twelth less than those yielded by paraffin oil.

Coal Gas.—In fixing the illuminating value and cost of the coal gas, the comparatively low average price of 5s. per 1000 cubic feet was taken, and the photogenic power of the gas was based upon 28 standard sperm candles. There are many places in Scotland where the price of the gas is higher than 5s., and some towns where it is lower; and there are few towns where the standard of 28 candles is exceeded, whilst there are a number of places where it is less. The adoption of the standard of 28-candle gas at 5s. per 1000 cubic feet, is within rather than above the average cost of gas.

Knowing well that the form and size of burner employed in the consumption of the gas had a most material bearing upon the illuminating or photogenic power of such, it was arranged that all the trials should be made with the union or fish-tail burner (which yields a higher photogenic return with 28-candle gas, than any other form of burner), whilst the sizes of the burners were Nos. 5, 4, 3, 2, 1, and ·5. Care

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was taken to regulate the pressure, so that each burner should consume as nearly as possible the exact amount of gas in cubic feet, which the respective number indicated. Thus, No. 5 burner passed 5 cubic feet, No. 4 consumed 4 cubic feet, &c. The following short table gives the experimental results obtained in these trials :—

Jet.	Consumpt. of gas per hour.	Evolved light equal to
No. 5, . .	5 cubic feet.	28 standard sperm candles.
No. 4, . .	4 „	20·8 „ „
No. 3, . .	3 „	13·8 „ „
No. 2, . .	2 „	7·8 „ „
No. 1, . .	1 „	3 „ „
No. 0·5, . .	½ „	1 „ „

In glancing at these results, there is manifestly a great loss of light as the size of the jet is diminished, and probably the difference will be better observed if the data given above be calculated into the light in standard sperm candles, capable of being obtained from a given volume—say, 5 cubic feet—of the gas transmitted through the various sized burners. Thus, 5 cubic feet of gas consumed at a

No. 5 jet evolves a light equal to			28	standard sperm candles.	
No. 4	„	„	26	„	„
No. 3	„	„	23	„	„
No. 2	„	„	19½	„	„
No. 1	„	„	15	„	„
No. 0·5	„	„	10	„	„

So that we lose 2 candles going from No. 5 to No. 4, or one-fourteenth of the whole light; and between No. 5 and No. 2, there is a loss of one-third of the illuminating power; whilst between No. 5 and No. 0·5, there is a disappearance of nearly two-thirds of the whole light.

The results given were the best which could be obtained during the consumption of the 28-candle gas in the various jets, with well regulated pressure, and they are higher than those given in other trials, where the pressure was purposely allowed to be excessive. Indeed, the loss in illuminating power when the gas is burned with undue pressure is large,

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and may be observed from the following experimental data, calculated for 5 cubic feet of gas.

Fish-tail or union jet.	Under full pressure. Consumpt. in cubic ft.	Under full pressure. Candle power for 5 cubic ft.	Under reduced pressure. Consumpt. in cubic ft.	Under reduced pressure. Candle power for 5 cubic ft.
No. 5, . .	4·99	28·14	4·99	28·14
No. 4, . .	4·94	24·02	4	25·98
No. 3, . .	4·36	20·48	3	22·89
No. 2, . .	3·14	15·16	2	19·46
No. 1, . .	2·49	10·94	1	14·95
No. 0·5, . .	1·68	7·04	0·5	10·12

It will thus be observed, that there is a serious loss of illuminating power when the gas is consumed under undue pressure; there being in the case of No. 2 burner, which is the more common size used in households, a difference of fully 4-candle power between the light obtained from 5 cubic feet burned at the proper pressure, and that given under excessive pressure.

Taking, however, the best results obtained from the 28-candle coal gas during its combustion from the various sized jets under proper pressures, and calculating the light evolved from such jet, for every 5 cubic feet consumed, into standard candle hours or units for 1d., the following results are obtained:—

No. 5 *jet* consumes 5 cubic feet per hour, and evolves a light equal to 28 standard sperm candles; consequently, the gas, in being burned from this jet, gives

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
28
60)5600
93·33 candle hours for 1d.

No. 4 *jet* consumes 4 cubic feet per hour, and gives a light equal to 26 standard sperm candles for every 5 cubic feet consumed; consequently,

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
26
60)5200
86·66 candle hours for 1d.

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No. 3 *jet* burns 3 cubic feet per hour, and yields a light equal to 23-candle power for every 5 cubic feet consumed; therefore,

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
23
60)4600
76·66 candle hours for 1d.

No. 2 *jet* consumes 2 cubic feet of gas, and evolves a light equal to 19½ standard sperm candles for every 5 cubic feet burned; hence,

Coal Gas, at 5s. per 1000 cubit feet.

5)1000
200
19½
60)3900
65 candle hours for 1d.

No. 1 *jet* burns 1 cubic foot per hour, with the photogenic power of 15 standard sperm candles for every 5 cubic feet consumed; therefore,

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
15
60)3000
50 candle hours for 1d.

No. 0·5 *jet,* with a consumpt of half a cubic foot per hour, evolves a light equal to 10-candle power for every 5 cubic feet; consequently,

Coal Gas, at 5s. per 1000 cubic feet.

5)1000
200
10
60)2000
33·33 candle hours for 1d.

These results may be tabulated as follows:—

For every 5 cubic feet of Gas consumed.

No. 5	jet gives a light equal to	93·33	candle hours for		1d.
No. 4	„ „	86·66	„	„	1d.
No. 3	„ „	76·66	„	„	1d.
No. 2	„ „	65	„	„	1d.
No. 1	„ „	50	„	„	1d.
No. 0·5	„ „	33·33	„	„	1d.

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The foregoing experimental data prove that where much light is required, coal gas is the cheapest of all the illuminants, provided the gas can be obtained of the quality of 28 candles, and at a cost not exceeding 5s. per 1000 cubic feet, and is burned from the larger sized jets. Under these circumstances, and paraffin oil at 2s. per gallon, the gas gives 93⅓ candle hours in No. 5 jet, 81⅔ candle hours in No. 4 jet, and 76⅔ candle hours or units in No. 3 jet; whilst the paraffin oil in Doty's lamp yields 66 candle hours or units for the 1d.; but the gas only gives 65 candle hours in No. 2 jet, 50 candle hours in No. 1 jet, and 33⅓ candle hours in No. 0·5 jet for the 1d. Consequently, whilst the gas is a cheaper illuminating agent in the three larger sized burners or jets, the paraffin oil is cheaper when the gas is consumed in the three smaller jets.

Summary of Results.

The following table will exhibit at a glance the relative illuminating power and photogenic value of the different luminants, taking each as they were burned:—

½d.	dip or tallow candle	gives	3	hours of	1¼	candle power for	½d.
¾d.	„	„	4½	„	1¼	„	„ ¾d.
1d.	„	„	6	„	1¼	„	„ 1d.
Composite candle (average)		„	5½	„	1·1	„	„ 1d.
Paraffin candle (average)		„	4·27	„	1·49	„	„ 1d.

Common Flat Wick Lamps.

Sperm oil	gives	3·59	hours of	1·306	candle power for	1d.	
Rape oil	„	6·84	„	1·05	„	„	1d.
Whale oil	„	9·5	„	·9	„	„	1d.

Argand Lamps.

Sperm oil	gives	·69	hours of	13	candle power for	1d.	
Rape oil	„	1·25	„	11·33	„	„	1d.
Whale oil	„	1·57	„	9·8	„	„	1d.

Cottage Lamp.

Paraffin oil, at 2s. per gallon, gives 9 hours of 6-candle power for 1d.

Parlour Lamp.

Paraffin oil, at 2s. per gallon, gives 6 hours of 9-candle power for 1d.

Dining-Room Lamp.

Paraffin oil, at 2s. per gallon, gives 4½ hours of 12-candle power for 1d.

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¾-inch Argand Lamp.

Paraffin oil, at 2s. per gallon, gives 6 hours of 9-candle power for 1d.

Doty's Lamp.

Paraffin oil, at 2s. per gallon, gives 6 hours of 11⅓-candle power for 1d.

No. 5 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 3⅓ hours of 28-candle power for 1d.

No. 4 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 4·16 hours of 20·8-candle power for 1d.

No. 3 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 5·55 hours of 13·8-candle power for 1d.

No. 2 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 8·33 hours of 7·8-candle power for 1d.

No. 1 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 16·66 hours of 3-candle power for 1d.

No. 0·5 Jet.

28-candle gas, at 5s. per 1000 cubic feet, gives 33⅓ hours of 1-candle power for 1d.

Cottage Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 12 hours of 6-candle power for 1d.

Parlour Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 8 hours of 9-candle power for 1d.

Dining-Room Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 6 hours of 12-candle power for 1d.

¾-inch Argand Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 8 hours of 9-candle power for 1d.

Doty's Lamp.

Paraffin oil, at 1s. 6d. per gallon, gives 8 hours of 11⅓-candle power for 1d.

From the foregoing table it follows, that a cottager will consume a 1d. tallow candle in 6 hours, and will only get 1½-candle power of light; whilst, if he purchases paraffin oil at 2s. per gallon, he will obtain, for every pennyworth of

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paraffin oil consumed in a common small lamp, 9 hours' light of 6 candle power. The most economical of candles, therefore, is beat by paraffin oil so completely, that the latter will burn half again as long a time and give nearly five times the amount of light during the whole period. A similar remark applies to whale oil, which is the most economical fatty oil, and a 1d. worth of which will burn for 9½ hours with less than a candle power, whilst the small paraffin lamp will practically burn as long and give six times the light for the same sum of money. Not only so, but if the cottager is content with the light of a single candle, and will reduce the size of the flame of the paraffin lamp by simply screwing down the wick, he may burn the paraffin oil with a single candle power, and spread his 1d. worth of oil over 54 hours, whereas his 1d. candle will burn out in 6 hours, and he cannot stop the rapidity of its combustion.

In contrasting the paraffin oil with coal gas, it will be found that paraffin oil is cheaper than gas in the No. 0·5 jet, as the following calculations will show:—

Paraffin cottage lamp,—9 hours of 6 candles, equal to reduced flame of 54 hours of 1 candle.	No. 0·5 jet coal gas gives 33⅓ hours of 1 candle.

The same remark applies to No. 1 jet, where

Paraffin cottage lamp,—9 hours of 6 candles, equal to reduced flame of 18 hours of 3 candles.	No. 1 jet coal gas gives 16·66 hours of 3 candles.

When the gas is burned from No. 2 jet, and the paraffin oil is consumed in a common parlour lamp, the gas beats the paraffin, for

Paraffin parlour lamp,—6 hours of 9 candles, equal to reduced flame of 6·92 hours of 7·8 candles.	No. 2 jet coal gas gives 8·33 hours of 7·8 candles.

But when the paraffin oil is consumed in Doty's lamps the two luminants are practically equal, for

Paraffin Doty's lamp,—6 hours of 11½ candles, equal to reduced flame, of 8·71 hours of 7·8 candles.	No. 2 jet coal gas gives 8·33 hours of 7·8 candles.

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With coal gas at 5s. per 1000 cubic feet and 28 candle power, the gas is cheaper than paraffin oil when the gas is consumed in the No. 3 jet, but if the gas cost 5s. 8d. per 1000 cubic feet, the two illuminating agents are equal; thus—

2 reduced Doty lamps will yield 4·92 hours of 13·8 candles.	No. 3 jet coal gas gives 5·55 hours of 13·8 candles (at 5s.), but 4·90 hours of 13·8 candles, when the gas costs 5s. 8d. per 1000 cubic feet.

The paraffin oil, and gas from No. 4 jet only become equal when the gas costs 6s. 6d. per 1000 cubic feet; thus—

2 reduced Doty lamps afford the light of 3·26 hours of 20·8 candles.	No. 4 jet coal gas gives 4·16 hours of 20·8 candles (at 5s.), but 3·20 hours of 20·8 candles when the gas costs 6s. 6d. per 1000 cubic feet.

The gas is superior to paraffin when the No. 5 jet is used, until the price of the gas reaches 7s. per 1000 cubic feet; thus—

3 reduced Doty lamps afford the light of 2·42 hours of 28 candles.	No. 5 jet coal gas gives 3⅓ hours of 28 candles (at 5s.), but 3·28 hours of 28 candles when the gas costs 7s. per 1000 cubic feet.

The above comparisons are drawn out on the basis of the photogenic value of the gas and paraffin oil for ½d., and on the assumption that the coal gas is of 28 candle power when consumed at the rate of 5 cubic feet per hour from a No. 5 fishtail or union burner; but in many places the gas does not come up to this standard, and granting that the gas can be purchased at 5s. per 1000 cubic feet, and the paraffin oil at 2s. per gallon, both luminants will still remain equal when the larger gas-jets are used if the quality of the gas comes below 28 candles. Thus, paraffin oil is as cheap as gas, when the latter is consumed at No. 3 jet, if the gas cost 5s. per 1000 cubic feet, and is of 24·70 candle power, or at No. 4 jet, when the same priced gas is of 21·53 candle power, or at No. 5 jet, when the 5s. gas is of 20 candle power.

The great convenience attendant on the use of coal gas, and the trouble connected with oil lamps, must always commend the gas for general use, wherever it can be obtained at reasonable cost, but where the charge is exorbitant, the

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paraffin oil will be found useful and serviceable in the illumination of not only small but of large apartments.

These two luminants are not antagonistic to each other in their chemical construction, or in the economical and photogenic results obtained during their combustion; and considering that the refined paraffin oil, costing 2s. per gallon, becomes almost equal to gas when the ordinary sized jets are used, the question may be asked, if it be not possible to experiment with the crude paraffin oil in our gas retorts, so as to get cheap illuminating gas from it. I know that great difficulties are in the way of obtaining permanent gas from paraffin oil, but considering that crude paraffin oil can be purchased at a sixth of the price of the refined oil, it appears probable that if some method of distinctive distillation could be devised and followed out, where the crude oil could be broken up into gas which would not condense in the gasometers or pipes, a great and important step would be taken in the advancement of the manufacture of coal gas. Cannel coals are not so cheap as they were, and the shale beds are of vast extent and extremely prolific of oil; so that I cannot resist the thought that the future of gas making will lie in the discovery of a practical process for transmitting crude shale oil into our gas retorts, and obtaining therefrom a permanent gas of high photogenic or illuminating power.

On Water Supply. By STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry.*

The subject which I have now to introduce to the notice of the Fellows is probably the most important of any which has occupied our attention for many years; and the Royal Scottish Society of Arts is peculiarly fitted as the learned body before which the subject ought to be discussed. We profess to deal with the applications of science to everyday life; to its bearings upon the progress of the arts and manufactures, as well as its influence on sanitary matters. More-

* Read before the Society on 8th January 1872.

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over, the subject is one which specially concerns Edinburgh at the present time; and if as a Society, or as individuals, we can do anything to settle public opinion on this all-important matter, we are bound to do so—especially considering that, at this moment, the subject is an open one for discussion, and we may all feel at liberty to state freely and candidly what we do know about it.

In introducing the subject, I will endeavour to speak on all points from personal knowledge, and without bias, in the full hope and expectation that those Fellows of the Society, who either agree or disagree with me, may as freely and candidly express their views. The more the matter is discussed, I believe the sooner will we arrive at the truth, and at a common understanding with each other as to all the standards or essentials in water supply. The subject may be discussed under several divisions—

I. Quantity of Water.
II. Quality of Water.
III. Vegetable and Animal Life in Water.
IV. Action of Water upon Lead.
V. Nature of Gathering Ground.
VI. Effects of Filtration.

I. *Quantity of Water.*

The primary uses of water are for drinking, cooking, and washing. So far as drinking and cooking—dietetic—purposes are concerned, the quantity of water absolutely required is comparatively small—probably a gallon a-head might suffice; and the amount necessary for personal ablutions might be reduced to another gallon, being for primary purposes, *in primitive fashion*, two gallons a-head per day. But the cleansing of clothes, and of furniture, as well as the floors, walls, and stairs of houses, necessitates a much larger supply. Even the smallest house, with its modicum of furniture, and the scantiest of clothing, make large demands upon water. Still more so, when the tendency of the present age is for all classes to live better than their forefathers; to have more roomy and airy houses;

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and to use more underclothing, and have more change of such—each necessitating more consumpt of water for their thorough and efficient cleansing. Even personal ablutions, as they ought to be carried out, by the periodic cleansing of the whole body—in baths where such are available, and in tubs where baths are too great luxuries—demand an increasing supply of water. And then our plan of drainage and sewerage, coupled with the water-closet system, has formidable and earnest claims upon quantity of water for the removal of impurities, not only from our houses into the sewers, but even more so from the sewers themselves. It may be a question whether the water system, for the removal of night soil and other impurities, is a correct one, as now carried out. I have grave doubts about it, unless quantity of water can be ensured at all times. The condition of the sewers in towns—built piecemeal as they are—is certainly not the best. Accumulations of fœtid matter are common in these underground tunnels, evolving pernicious gases, which permeate our house drains, and contaminate the air of our rooms. Means ought to be at hand for the weekly flushing of sewers, so as to remove deposited putrefying matter, and thus ensure mechanical cleansing. But equally important, as a sister aid, is the constant small run of water through sewers, which leads to chemical cleansing, for the water contains gases in solution, of which oxygen is one, and while flowing over deposited matter, or even over the foul bottom of the sewer, the dissolved oxygen burns up or oxydises the noxious gases evolved, and thus removes these from our drains and sewers.

I have little faith in the separate system of drains. At present there is a chance of flushing by rainfall, and the consequent removal of foul matters; but by the separate system of conduits, such periodic flushing will be practically lost. Still less have I faith in the water-closet system introduced into small houses. It is an element of danger at any time, and where little care is taken, becomes highly dangerous. Much better to retain and amplify the present can system, or adopt the Liverpool method of tank closets in the yards attached to each tenement, or the more trouble-

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some, but certainly less dangerous system of the earth closet for each land of houses.

II. *Quality of Water.*

All natural waters contain more or less saline ingredients, and all possess a greater or less amount of organic matter, besides gases, in solution. Neither the saline nor the organic matters are necessarily *impurities.* They may be the natural constituents of wholesome waters. The saline matters are principally carbonate of lime (chalk), sulphate of lime (stucco), and chloride of sodium (common salt), with a small proportion of magnesium compounds. The organic matter is of vegetable origin, and is not putrescent.

Certain saline matters may, however, render water unsuitable for primary uses, as hydrosulphuric acid (sulphuretted hydrogen), which is present in sulphureous waters, and the carbonate and sulphate of iron, which are found in chalybeate waters. Even excessive proportions of the ordinary constituents communicate undesirable properties upon water, as much carbonate and sulphate of lime constitute unduly hard or calcareous waters, and much chloride of calcium and chloride of sodium yield saline purging springs.

As a general rule, the larger the proportion of saline matter the greater the degree of hardness. Thus the average of many analyses gave as follows:—

	Saline Matter in gallon.	Hardness.
Spring water from Pentlands, . .	12 grains.	7°
Reservoirs on north side of Pentlands,	8 „	4½°
Do. on central do.,	5 „	3°
South Esk water, ...	4½ „	2½°
Heriot water, ...	5½ „	4°
Talla water, ...	3 „	2°
St Mary's Loch water, . . .	3 „	2°

For cleansing purposes there is a decided disadvantage in hard water. It necessitates more or less waste of soda and soap. Independently of that, for personal ablutions, soft water is much more agreeable and effective. For cooking purposes a comparatively soft water is advan-

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tageous. It is more effective in extracting the nutrient value in infusions and extracts, such as tea and coffee, soups, &c. Hard waters are positively a hindrance in cooking many articles, as insoluble compounds are formed with the lime. Besides, hard waters lead to the incrustation of vessels, which necessitates extra firing and a certain risk in the filling up of pipes, and the consequent explosion of boilers, &c. For drinking purposes it is of little moment whether the water is hard or soft, provided it is palatable, which more depends on the gases dissolved in the water than on the saline matters in solution. For instance, even hard water, when boiled or heated, and then allowed to cool, is very mawkish to taste; whilst even distilled water, when the distil-aerator is employed, is in all respects decidedly palatable.

The large proportion of lime in the ordinary articles of food renders it unnecessary that lime should be present in the water supply, and, moreover, the lime in water is in the form either of carbonate or sulphate of lime, which is not the principal state in which it is required for the wants of the animal frame, which makes great demands on the phosphate of lime for the building up and sustenance of the bony skeleton. For town supply a water containing not more than 5° of hardness is of first-class quality for all domestic purposes. When the degree of hardness ranges between 5° and 10° the water is of second-class quality, and when from 10° to 20° of hardness the water is of third-class quality.

The organic matter present in waters may be of various kinds. In ordinary natural healthy or wholesome water the organic matter is of vegetable extraction. It may be of a peaty nature, when a yellow shade of colour is observable, or of a non-peaty character, when the colour is not affected. The average quantity of organic matter in water is about two-thirds of a grain in the imperial gallon. The colour is very deceptive in this case, for the organic constituents are often present in as large quantity in colourless as in coloured waters. The presence of lime hinders the observance of the colour—due apparently to the formation of a colourless

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compound. A water containing much peaty matter, when treated with a very small amount of lime, and then filtered, becomes quite colourless. The same result takes place more slowly when carbonate of lime, in the form of shells or pieces of lime rock, are present in the filtering bed. A mixture of the peaty water with a hard water gives rise to a similar decoloration of the mixed liquids.

We must distinctly draw the line between the above or non-putrescent organic matter and putrescent organic matter, either of vegetable or animal origin. Marshy waters become impregnated with vegetable matter, which is liable to putrefaction, and hence marshy waters do not belong to the same class as those tinged with peat. There is a decided difference in the nature and proportion of the gases. Animal impregnations derived either from sewage or from highly manured fields give rise to the most dreaded contamination, which may, when the entrance of the impurity is direct, be visible to the naked eye; but when the organic matter has percolated through the soil, it may be in part oxidised into nitrates, and the water be obtained perfectly clear and sparkling, as well as cool and refreshing, and yet be positively unwholesome and deadly when partaken of for dietetic purposes.

The quantity of organic matter dissolved in the waters of the present Edinburgh supply, the South Esk, the Heriot, and the St Mary Loch districts, is close upon two-thirds of a grain in the imperial gallon, and there is practically no difference in the amount furnished by each water. This organic matter is entirely non-putrescent. Where the peaty matter is much greater in quantity, as in some of the compensation reservoirs on the Pentlands, the organic matter may be as much as 1½ grains to 2¼ grains in the imperial gallon. Even the water of Loganlea reservoir has one grain of organic matter in the gallon; whilst the highest proportion present in any feeder of St Mary's, or any portion of the loch, is ·79, or four-fifths of a grain, which is the quantity found in the Little Yarrow.

In waters which are contaminated by the products of animal matters derivable from sewage or from highly

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manured fields, the amount of organic matter ranges from 1 to 10 or more grains in the imperial gallon.

The gases dissolved in waters form one of the best guides as to the quality of the waters. These gases are mainly carbonic acid, oxygen, and nitrogen. The proportion of carbonic acid varies according to hardness, when such is derivable from carbonates; whilst the relative amounts of oxygen and nitrogen should be very nearly as 1 of oxygen to 2 of nitrogen. When the water is of a wholesome nature, and the organic matter is not putrescent, then such is the ratio of these gases; but where there is putrescence, the oxygen decreases to 1 to 3, or less, which is indicative of positively unwholesome properties being present in the water. For instance, in the course of the inquiry into the condition of the Water of Leith, I had occasion to make many testings which led to these results, and the subsequent analyses of many hundreds of waters received from all quarters has confirmed these conclusions. The gases dissolved in the waters of the Edinburgh or Pentland, South Esk, and St Mary's Loch districts are as follows, taking the average results of many experiments made on each set of waters:—

	Edinburgh Spring Water.	South Esk River Water.	St Mary's Loch and Feeders.
Carbonic acid, .	10	5	4½
Oxygen, . .	29	30	30½
Nitrogen, . .	61	65	65¼

In neither water, when kept for months in closed bottles, was there any practical difference in the quality of the gases or in any other property. The organic matter was, therefore, in all these waters of a non-putrescent and wholesome nature. At the same time, contact with the air and sunlight has a material influence on the organic matter, which is thereby oxidised, and tends to lessen in quantity, so that the water becomes more and more colourless in course of time.

III. *Vegetable and Animal Life in Water.*

All waters when exposed to the air become impregnated more or less with organisms. Even spring water, which has

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never seen the light of day till it is run into our house cisterns, very soon acquires organisms, especially in the warmer months of the year, and in the warmer situations in households. In wholesome natural waters, impounded in natural or artificial reservoirs or ponds, the vegetable growth consists mainly of fresh water algæ, which adhere to and grow on stones in the quiescent parts where there is little current, and where the stones do not roll over each other, but are stationary. Every Highland and Lowland loch is an illustration of this. Take the ponds on the Pentland Hills, for example. At Loganlee the embankment is incrusted with such algæ. In the running stream which flows from Loganlee to Glencorse reservoir, little of the algæ is to be seen; but as the water enters the Glencorse reservoir, especially at the north-west corner and side, there is abundance of vegetable growth, including the algæ. At Clubbiedean, which is a spring water reservoir, the embankment is thickly incrusted with vegetable growth, and at the upper part of the waste weir, which communicates with Torduff, the same algæ are growing most luxuriantly, whilst at the embankment at Torduff the same vegetation may be seen. Then go to Loch Katrine, Loch Lomond, Loch Lubnaig, or Loch Earn, Loch Venacher or Achray, Lochs Menteith, Chon, or Ard, or any other loch or impounded water, and at all the quiescent parts you have the same vegetable growth—the same fresh water algæ. Wherever there is a sheltered spot, and where the wind and the waves do not roll stones over each other, there you have vegetable growth or algæ. Similarly at St Mary's Loch, at parts of the north side where the stones are not disturbed, the vegetable growth is to be observed; but where rolled stones are abundant, as at the east end and north-east side, there is practically no growth whatever. In the Yarrow, which is the natural outlet of St Mary's Loch, wherever water is flowing along leisurely, algæ are to be found; but where there is a rapid current, little or no vegetable growth is to be seen. The same is observable in the Megget, and the other main feeders of St Mary's Loch. The vegetable growth is common to all the stones on the shores of all natural and artificial lochs and reservoirs, and

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to the more quiet running parts of streams, and is more evidence of purity in the water than of impurity.

The animal life visible in fresh waters consists mainly of minute organisms about the size of a pin head, and which are minute crustaceans, principally *Daphnia pulex* and *Cyclops quadicornis.* Of course, at the sides of all lochs and reservoirs, you can pick up the larvæ of insects, water scorpions, and other animal forms which live in-shore, and which are equally found in every impounded water, and in every running stream. The so-called water fleas, however, the *Daphnia pulex* and the *Cyclops quadicornis*, are the denizens of the water, and are distributed throughout the lochs, and are also found in house cisterns. The Cyclops is the more common, and seems to appear earlier in the season. In June they are abundant in every pond on the Pentlands, especially at Clubbiedean, Torduff, and Bonally. There are apparently fewer in Loganlee and Glencorse, which is probably to be explained from there being a constant current of water running through the latter. As the month progresses, the Daphnia becomes abundant, and they are especially numerous in the reservoir of Clubbiedean. On the face of the embankment the algæ are growing rather luxuriantly, so that there is much living vegetable matter, and such organic matter apparently forms excellent feeding ground for the fleas. In other lochs you find the same forms of animal life. In June, in Loch Lomond, you will everywhere find the Cyclops, not only at the side, but all up the middle of the loch, wherever a bottle is put down, the water which is drawn up always brings up some fleas. At Loch Katrine, all along the shores, including the region immediately surrounding the mouth of the tunnel leading to Glasgow, the fleas are present in the water, as well as at the piers, and throughout the whole length of the loch. You cannot lift a bottle of the water without finding the water flea. In St Mary's Loch the water contains few fleas as compared with the water of the Pentland ponds, which I believe is due to the current of water which is constantly flowing through the loch. In the warmer months, however, the Cyclops is seen distributed through the water, but I

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have seldom seen the Daphnia in any part of the loch. At the north-east end, where the Yarrow flows out, and where the proposed pipe for town supply was intended to be introduced, there is comparative freedom from fleas in the water, and even from the fresh water algæ which form the feeding ground of such. In August, more vegetable and animal life are to be found everywhere in all the lochs and reservoirs, but I may safely say that the number of fleas in the water of St Mary's Loch even at that time is certainly much less than the number to be found in any reservoir in the Pentlands, whether used for compensation or otherwise.

The water fleas are extremely delicate organisms. A very little alcohol added to the water kills them, and when the water is heated to a temperature of 100° F. they die at once. Any decrease in the amount of the oxygen dissolved in the water below the wholesome quantity quickly causes their death. Thus, when water containing the fleas is bottled up for a night, the majority, if not all of the fleas, will be found dead in the morning. Care must be taken to leave the bottles open, so as to ensure the continued aeration of the water, and thus enable the fleas to have the most wholesome of air in solution in the water. Fleas, therefore, are evidence of the purity of waters. They are never found in contaminated waters. Not a single flea was observed in the whole course of the experimental observations on the Water of Leith, from Coltbridge downwards. Any putrescent material introduced into the water will influence the quality of the gases in solution, and the fleas die by the foul air. These remarks apply equally to hard and soft waters. In running streams the fleas are found in all the quiet corners where the current is reduced to a minimum. Filtration through sand and gravel removes the greater number of the fleas, but not all. When examining the Torduff filtering beds in June of last year, I found the Cyclops in the newly filtered water, and during the summer the fleas were in the water transmitted to the city, as evidenced by their daily presence in the water supplied to my laboratory and house.

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IV. *Action of Water upon Lead.*

The common notion that soft waters act more upon lead than hard waters is erroneous. During a very lengthened experience as an analyst, I have found many more hard waters which acted upon lead than soft waters which did so. A natural water taken from a stream, lake, or spring, and containing the proper kind of ingredients—however soft—has no deleterious action upon lead, but when impurities are present in either hard or soft waters, they have a more or less powerful action upon lead. Thus, the impregnation of either soft or hard water with sewage products, or the drainings of highly manured land, confers upon the water the property of dissolving lead, which is mainly due to the action of the calcic nitrate in solution in the water. A similar result is traceable to marshy water which contains putrescent material. But no such action upon lead occurs with waters which have a peaty tinge. The late Prof. Miller, of King's College, London, even said that the peaty matter was a preservative against the water acting upon the lead, but I scarcely think it necessary to consider that such is the case.

Hard waters are more likely to be contaminated with impurities, because they generally rise in lowland districts where there is a considerable population, which directly or indirectly send sewage into the streams, and where the arable land is heavily manured. Soft waters, on the other hand, can scarcely be polluted at all, for they generally rise in hilly districts, where there is a scattered population and scanty cultivation, so that neither sewage nor the drainings of highly manured fields can contaminate them.

The proper mode of testing the action of water upon lead is to proceed to bring the lead and water in contact with each other as they would be in ordinary use. The placing of pieces of sheet-lead with fresh cut edges, and often with scraped surfaces, in the water contained in a bottle, is not to be commended, as the results give an exaggerated notion of the power of the water to act upon lead. Indeed, there is no natural water which may not in this way be shown to

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act so powerfully on lead as to be hurtful and poisonous. The proper method of testing the action is to bring the water in contact with the lead having its natural skin or surface, which is probably a thin film of an oxycarbonate of lead. A short length of lead pipe, an inch in diameter, with the one end beaten close, or a lead cistern soldered in the ordinary way, may be employed in the experiments. The pipe or cistern is rinsed out with the water to be examined, and the tube or cistern is then filled up, and the water allowed to stand in it for at least twenty-four hours. In my later experiments I have supplemented those smaller trials with a cistern to which there is attached twenty feet of lead pipe and a brass cock, the whole being soldered and fitted together in the same manner as an ordinary house cistern with pipe and cock is constructed. Working, therefore, with the short length of pipe, the small cistern, and the house cistern and pipe, I find that the present Edinburgh spring or pond water, the South Esk water, the Heriot water, and St Mary's Loch water, act practically the same upon the lead. Thus, when the lead is fresh and new, the action during the first twenty-four hours is to the extent of $\frac{1}{10}$th of a grain of lead in the gallon of water, which decreases in a week to $\frac{1}{40}$th of a grain, even when allowed to stand for three days, and thereafter the action does not exceed the $\frac{1}{80}$th of a grain even when the water remains in the cistern. Where the water is run in and out, as takes place in daily use in households, the proportion of lead in solution becomes infinitesimal, and cannot be recognised even by chemical tests. Even at the first the action is far within the limits of safety, and, certainly, when a few days are past, the water ceases practically to have any solvent power over the lead. A word of caution requires, however, to be given in regard to dirty cisterns, especially when lime falls into them, as a sediment is often found in cisterns which contains much sand and clay, accompanied by lime and much carbonate of lead in fine division. Where such is the case, the rapid influx of the water may stir up this sediment, and cause part of the carbonate of lead to be mechanically diffused through the water, which may thus exert

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deleterious properties. All cisterns should be cleaned out once a month with a soft brush, so as to avoid the contamination alluded to here. My experiments on the action of water and saline matter upon lead are very numerous, and must be reserved for another paper.

V. *Nature of Gathering Ground.*

That water for town supply should not be collected in the neighbourhood of populous places, either from the surface or from wells, will be admitted by all. Professional acquaintance with the water supply of many towns and villages has led me to the conclusion, that at least three-fourths of all the well waters in populous places are contaminated with sewage, and are unwholesome. That water should be collected from cultivated districts is scarcely less to be deprecated. The fields are often highly manured, sometimes with police manure, and the drainings from such are more or less polluted with noxious ingredients. Even districts which are likely to be chosen for breaking up by farmers—comparatively flat land or agricultural areas—should not be fixed upon for the water supply of large towns. Numerous instances can be adduced of water of good quality at one time becoming thus contaminated by the breaking in and manuring of land, leading to unwholesomeness in the water, as well as the power to act more or less energetically upon lead.

Districts having hard water are more likely to be influenced by the progress of agriculture, because they are generally more flat, whilst soft water districts, being more hilly as a rule, are less capable of being turned to arable purposes, and hence remain strictly pastoral. The drawback to soft water districts is the presence of more or less peat, which communicates a greater or less tinge of colour to the water; but surely the mere appearance of a water is not to be sacrificed to unwholesomeness. The majority of Highland and Lowland lochs, and the districts draining into such, as also the available collecting grounds for artificial reservoirs, must necessarily be in localities where there is some peat, and such is certainly as abundant in the High-

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lands as in the Lowlands. It is equally sure that Highland lochs as well as Lowland lochs contain water which is tinged with peat. A slight impregnation of the water with peat should not be considered objectionable, as it is not unwholesome. No pernicious effects have ever been traced to such. Difficulties have arisen from mixing up *marshy water, peaty water, and sewage impregnated water* all together. Many towns are supplied with the so-called peaty water, including Glasgow, Aberdeen, and Inverness, and there is absolutely no proof whatever of any noxious quality being derived therefrom. Even in Edinburgh we drink in part the water from Loganlee reservoir, which is markedly peaty.

The South Esk, Heriot, Talla, and St Mary's Loch districts contain some peat on the tops of the hills, but practically the effect of such upon the waters of the districts is little. As the South Esk, Talla, and Heriot waters are not naturally impounded, there is a difficulty in knowing exactly the average composition of such waters over the year; but we may judge from analogy in the case of the St Mary's Loch water, where the loch is certainly large enough for the mingling of the waters, being three miles in length by about half a mile in breadth, and being connected by a short narrow streamlet to the Loch of the Lowes, which is a mile in length, and may be regarded as an extension of the larger loch. At the east end, or lower part of St Mary's Loch, near where the water flows into the Yarrow, and where it was proposed to draw off the supply for the city, the average of the whole waters may be obtained. This water has been collected at all seasons of the year, and the composition, as determined by chemical analysis, has been practically the same at all times. The Megget stream, which is the principal feeder of the loch, flows in on the north side with a deep channel, which, at a distance of 150 yards from the mouth of the stream is 90 feet deep, with a stony or pebbly bottom, as evidenced by the plumb striking hard upon it. Towards the east of the Megget the ground generally shallows near the side, which is caused by a delta being formed there, consisting of fine silt composed of the comminuted graywacke rock of the district, with some

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broken stalks of brackens, a little grass, and a few minute fragments of peat. These were the results of dredging, and also of the hollowed out lead plunger or plummet. On chemical examination of the silt when dried, not one per cent. consisted of organic matter. I have never seen cleaner silt dredged or taken from the bottom of any loch. In all the ponds and reservoirs in the Pentlands you have similar finely divided earthy matter, accompanied by a minute proportion of organic matter thrown down, the only differences being that in the Pentland ponds the silt is more ferruginous and ochrey in its nature, and when agitated causes more discoloration of the water. At certain parts, as at the north-west side of Glencorse reservoir, where the burn from Loganlee enters, the silt contains a much larger proportion of organic matter, there being in some samples examined from 5 to 10 per cent.

In lifting samples of water for chemical analysis, care should be taken that the water is collected as it naturally flows in the stream or loch, and that the banks or bottom be not disturbed. Where the water is to be taken from the side, it is better to lift it in a large spoon lined with porcelain and attached to a wooden pole, so that the operator may stand firmly on the bank without disturbing the stones or earth on the immediate brink, and be able to stretch out the instrument some feet into the stream or loch. Where no such lifter is used, and the collector stands on earth or stones immediately alongside, or in the water course, and dips down the bottle, there is almost certain to be disturbance of the bottom, and more or less sedimentary matter passing into the bottle. Where the water is to be collected at depths not exceeding 6 feet, I employ a galvanised iron cylinder fitted up with tubes and stopcocks, which can be opened and closed when the cylinder is lowered to the required depth. Where it is desirable to take the water from greater depths, say 20, 50, or 100 feet, I use a galvanised cylinder fitted up with a valvular arrangement, which remains open when the apparatus is being lowered in the water, and closes at once on the descent being arrested at any point. In order to admit of the appa-

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ratus being lowered perpendicularly with sufficient rapidity to ensure the constant current of water through the cylinder, a hollowed out lead plunger is attached to the lower part, which not only performs the duties of sinking the apparatus rapidly, but also serves to bring up a portion of any sediment or silt which may be at the bottom. The line attached to the cylinder is marked off in fathom lengths, so that the depth may be at once known. The instruments described were employed in the collection of all the waters from the Pentland reservoirs and St Mary's Loch; and in every case the waters collected at great depths agreed in chemical composition and properties with those lifted from the surface of the respective reservoirs or lochs.

The South Esk, Talla, and Heriot waters, not being impounded in bulk, excepting the comparatively small amount lodged in the Portmore Loch, which belongs to the South Esk district, no direct observations could be made in these waters exactly similar to those carried out at St Mary's Loch. But considering the composition of the waters referred to, especially those of the Heriot and South Esk, which in ordinary times are slightly harder, there is every reason to believe that were these waters impounded in artificial reservoirs capable of retaining the flood waters of the district, the average composition of the water would show less saline matter, and the degree of hardness be smaller, so that practically they would approach the average composition of the waters of the St Mary's Loch district—both in quantity of ingredients and degree of hardness.

In all large lochs and reservoirs, the waters become uniformly distributed during their retention in and passage through the loch or reservoir. You pick up at all depths water of the same colour and quality, and possessing the same saline, organic, and gaseous constituents. In the ponds on the Pentland Hills, water taken from the surface of the reservoir, and that collected near the bottom, were practically identical in chemical composition and all other properties. The same remark applies to the water of St Mary's Loch, which taken either from the surface or from 100 feet in depth, was essentially the same in colour as well as

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in chemical and other properties. The temperature of the water was slightly different. On the 27th May, I found the water at a foot from the surface to be 53° F., whilst at 60 feet in depth the temperature was 51° F., there being thus a difference of 2°. The slight film of water which floats immediately on the surface of all impounded waters varies much in temperature from day to day, according to the warmth of the air, but the daily influence of the sun does not extend in calm weather to more than two or three inches from the surface. The general influence of the season's temperature, however, must be exerted much further down. The difference in temperature between water taken at various depths affords no evidence whatever that the water has remained in the lower depths of the loch from winter to winter, or that the water should be called stagnant in any sense of the term. It is really fresh in every view of the question. The difference in temperature may be fairly ascribed to the effects of three causes, viz., (1) the action of the sun's heat on the surface; (2) the cooling influence of the ground; and (3) the introduction of spring water.

The first cause is very apparent. The direct sun's heat can only affect the water to a certain depth, but partly by conduction and partly by convection, and the consequent establishment of currents, the heat will, during the summer or warmer months, penetrate down some distance.

The second cause of the difference in temperature is the cooling influence of the ground. The sun's heat can only pass a comparatively short distance into the earth. Take a hill side, and, during the summer or warmer months, bore a hole in the ground. As the descent is made, the temperature of the ground decreases, being further removed from the influence of the external heat, and at a varying but certain depth you arrive at a point which neither the heat of summer nor the cold of winter can affect. This is the region of uniform temperature, and is much lower than that of the surface of the soil in summer weather. If a loch fills up a valley to some height, the ground which it covers being removed from the heating effect of the solar orb, must approach the degree of uniform temperature, and all water lying in such a valley

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must be cooled down from day to day by the lower temperature of the ground forming the sides and bottom of the loch or reservoir. The cooling effects of the ground in the region of uniform temperature is very well observed in the case of the spring water from the Pentlands. These springs owe their origin to rain water falling on the hills, which permeates the ground, and then issues as springs. During the summer, the rain water, when it falls upon the ground, has an average temperature ranging between 50° and 60° F., whilst, when it issues as spring water, the temperature ranges from 40° to 44°.

The third cause of the difference in temperature is the introduction of spring water. In valleys where the water is not impounded by natural or artificial means, numerous springs crop out from the hills in every direction. These springs are more numerous near the foot of the hills, where there is more drainage area, than near the top, where the collecting area is comparatively small. Trace a streamlet up such a valley in summer time, when the rainfall is at a minimum, and you will find that whilst the tops and the upper ridges of the hills are dry and parched, and scarcely a spring is to be seen, yet down near the valley you will see numberless little trickling rills flowing, which are formed from springs near the foot of the hills, and gradually adding their quantity of water to a common stock, ultimately form the streamlet. The temperature of the water in these springs as they issue forth from the hill side will range from 40° to 44°, whilst as the streamlet progresses the water becomes more heated by the summer warmth. Now, raise an embankment in such a valley. The mere damming up of the water to a height to cover these springs will not stop the issue of the cool water therefrom, and when the reservoir has been formed, the water contained therein will necessarily differ in temperature at various depths, as (1) the sun heats up the mere surface water; (2), the cool ground tends to keep down the temperature of that which is lying in the bottom; and (3), as the comparatively cold springs constantly make accessions to the common stock of water.

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The South Esk district is full of such springs, which issue forth from the ground, and the raising of an embankment will not stop the escape of water, but will simply store such. The springs will still run and be feeders of the reservoir. So in the Talla district, where, on the very site of the proposed reservoir, some very fine springs are observable. Construct an embankment, and these springs, though then invisible—because covered with water—will still continue to flow and be one source at least of supply to the reservoir. Then go to St Mary's Loch district, traverse the Megget valley in seasons of summer drought, when little or no rain has fallen for months, and all up the valley you meet little streams fed by springs issuing out of the hill side. There is no other source of the water during a dry season. Embank the Megget, and these springs would still be the main sources of water in the drier months, and contribute also enlarged quantities in winter and more rainy seasons when the springs are running full. Similarly, no doubt, in the connecting valley of St Mary's. Were the loch drained, all analogy proves that springs would be found issuing from the hill sides down to their very base, and there is no reason to consider, because the loch is naturally embanked, that the springs have ceased to run, or that the special district of St Mary's is exempt from such springs as we find in every other valley.

VI. *Effects of Filtration.*

All reservoir waters are improved by filtration. Mechanical impurities, such as finely divided clay from artificial banks, and organisms of all kinds, are arrested in great part. Chemical impurities, however, such as the drainings of highly manured fields, or the products of decomposing sewage, are not removed by a mechanical filter. Any slight tinge of colour is lessened, especially if the filtering bed contain shells. One of the best evidences of such is observed in the water of Loganlee, as it passes through the embankment, and flows on to Glencorse reservoir. The water of Loganlee is decidedly of a peaty tinge; whilst, when it filters through the bank, the shade of colour is reduced very

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much. There are two ways of determining the colour of water. The best method is to introduce the water into a testing tube about sixteen inches long and two inches wide, the one end of which is closed with a piece of plate glass. This apparatus has been in use for at least half a dozen years among all analytical chemists who have devoted attention to the subject of water analysis. The tube is filled with the water to be examined, and is held in the hand over a piece of white paper, while the operator looks down the whole length of the column of liquid. Different shades and degrees of colour can be very easily and correctly distinguished in this manner. Another plan which can be resorted to in all lochs and reservoirs, is to lower a white porcelain plate, about six inches in diameter, and observe the colour which the water imparts to the plate at certain depths, as also the exact depth at which the plate disappears from the eye. Now, using the latter method of determining the colour, the porcelain plate, when lowered in Loganlee reservoir, disappeared at four feet from the surface; whilst, when the same plate was lowered in Glencorse reservoir, it was still though barely visible at 10 feet from the surface, and only became invisible at 12 feet. In trying the same plate in other ponds and reservoirs, it disappeared as follows:—In the Pentland reservoirs, Torduff, at 9 feet 10 inches; and Clubbiedean, at 12 feet 2 inches. In Portmore Loch, part of the South Esk collecting ground, at 15 feet; and in St Mary's Loch at 12 feet; whilst in the compensation reservoirs on the Pentland Hills, which are now used for motive power, the plate disappeared at much less depths, being at Harelaw, 4 feet; Thriepmuir, 3 feet 6 inches; Harperrig, 2 feet 11 inches; and at Crosswood, 1 foot 11 inches.

During the conveyance of all water to town in built conduits, tunnels, or pipes, the water becomes of a uniform temperature throughout the year, and is delivered about 44° F., so that neither the extreme heat of the surface water of a collecting loch or reservoir in summer, nor the extreme cold of winter, materially affects the temperature of the water as delivered from the mains.

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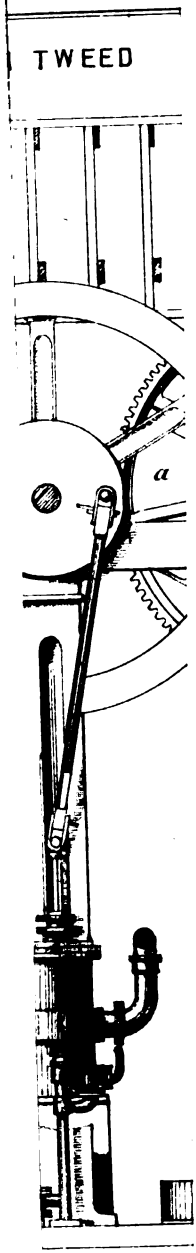

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I have thus endeavoured to mention a number of points which are of importance in water supply. I hope that the paper will serve the purpose of enabling us to know what lochs and reservoirs are, and what we may expect to find in them. My earnest wish is that in Edinburgh we may have an abundant supply of good water, and that we may be no more stinted in water than we are in air.

On the Water Supply of the Town of Berwick-on-Tweed. By Alexander Leslie, C.E., F.R.S.S.A., Assoc. Inst. C.E.*

The question of obtaining an additional supply of pure water for the town of Berwick-on-Tweed has occupied the attention of the local authorities of that place for a considerable number of years, and it was only a few months ago that that problem was satisfactorily solved. It was the same with this town as I have repeatedly observed in the case of many others, viz., that the more numerous the sources of supply which are at disposal, the greater seems the difficulty of fixing on any one particular source to select; whereas when there is perhaps only one scheme which is pointed out as being the proper one to adopt, the chances that it will be introduced without delay are very much in its favour. At all events, numerous reports were given in, and different schemes proposed, considered, and in turn laid aside, from the year 1858 to 1869, when things getting too bad to be any longer endured, it was at last resolved to set to work in earnest, and the present addition to the supply which has lately been introduced was the result of the determination.

Before giving any description of the works which have lately been completed, I propose to refer shortly to the state of things which existed up till that time, and to allude to the various schemes which were in turn proposed as eligible sources of supply, as I fancy that they may be of some interest to this Society.

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* Read before the Royal Scottish Society of Arts on 22d January 1872.

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The earliest accounts of the introduction of a water supply to this town are to be found in Fullar's History of Berwick, which refers to the construction, in 1789, of the Low Service Reservoir in Castlegate, for the purpose of receiving the water from two springs, named the North Course and Nine-Well-Eyes. These two supplies met in a settling well, situated a short distance from the town, near where the present cemetery stands, and were led thence to the present Low Service Reservoir in a stone-built conduit. From this reservoir wooden pipes were laid to supply the town, and each householder was allowed to take a pipe from the main into his house for the small sum of 5s. per annum. Three-inch lead pipes were afterwards substituted for the original wooden ones—several yards of which were discovered when the new main pipe was being laid last summer, and were claimed by the corporation as their property.

The wants of the inhabitants were easily satisfied in those days, as may be gathered from the following remark contained in the history before alluded to, which says—"There are many accounts of the people of Berwick having suffered the horrors of fire and bloodshed; but they never seem to have suffered from thirst, having always had an unlimited supply of water." This statement will seem curious enough when we learn that the total supply was not more than 10,000 gallons per day; so the population, varying as it did from 7000 to 8000, could not get more than about 1¼ gallons per head. The fluctuation in the population was owing, doubtless, to the fact of Berwick being in those days a garrison town.

The town of Berwick, as is known to most of you, is situated on a steep slope, which rises from the sea-level to about the level of 180 feet above that, which fact of itself renders the question of an equal distribution of water a matter of considerable difficulty.

About the year 1850, reports were obtained from Mr Geo. Bruce, C.E., in which he proposed to introduce water from Horncliff Burn, with an alternative scheme for pumping water from the river Whiteadder at New Mills into a

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reservoir to be erected at White Dam Head, which latter was estimated to cost L.3000.

Nothing, however, resulted from this investigation and report, as there were legal difficulties in the way which prevented the corporation from applying their funds to such a purpose as the introduction of a new water supply. In this same year the passing of the Health of Towns Bill resulted in the formation of a local board of health, who have ever since that time conducted all inquiries as to sanatory improvements and such like, and whose first care was to apply to Mr Rawlinson of London, who furnished them with a report on increased water supply, and also on town drainage, which resulted in both schemes being carried out. The water scheme consisted in the construction of a store reservoir at New East Farm, and the formation of an aqueduct from it to a high-service reservoir placed at the level of about 200 ordnance, so as to command all the high districts of the town. The drainage area from which the store reservoir is supplied is 338 acres, which, with the extremely small quantity of ten inches of available rainfall per annum, which is common to all the surrounding district, would yield an annual amount of twelve million cubic feet, which is equal to a supply of 20 gallons per head per day to a population of 10,000, provided that all that amount could have been utilised; but the store reservoir was constructed to hold only 7½ million gallons, or thirty-five days of the above quantity, which experience soon proved to be too small an amount. The capacity was, however, increased to 8½ million gallons, or forty days' supply, by raising the level of the water by means of stop-planks placed across the waste weir. This small amount of storage was found perfectly insufficient to render available anything but a very small proportion of the total rainfall, as during the wet period of the year large quantities ran over the waste weir and were lost; and another source of loss consisted in a considerable leak in the embankment, caused by carelessness on the part of the contractor, who had left some of his planks lying across the puddle-dyke, and which permitted very large quantities to escape.

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This scheme, which was introduced in 1854, at a cost of L.8200, was before long found to be insufficient for the wants of the town.

In 1858 Mr Rawlinson again reported to the Local Board at great length, and proposed several pumping schemes, none of which, however, were carried out; and they very soon after sought the advice of Mr John Reid, C.E., then of Montrose, who, in an able and exhaustive report of date December 1858, recommended that a pumping scheme should be adopted from the Whiteadder at Edrington Mill into a high-level cistern. That scheme shared the fate of its predecessor, and was not carried out.

Nothing more was done in the matter till 1862, when Mr Leslie was applied to, at the suggestion of Mr Rawlinson, who on account of an official appointment was precluded from undertaking the work himself, and he furnished them with a long report, in which he proposed three different sources of supply,—being first an additional store reservoir below the existing one at New East Farm, which would increase both the available drainage area and also the storage for utilising the yield of it, which, as we have seen, was much needed, and the laying of a new 6-inch iron pipe from there to the high-service reservoir. This reservoir, which was calculated to hold 4 million cubic feet, or 25 million gallons, was intended to have an additional drainage area of 338 acres, making in all 676. This area was calculated to yield 24 million feet per annum, which is equal to 427,550 gallons per day. This scheme was estimated to cost L.8500; and there were alternative reservoirs proposed, but not recommended, as even the largest one was too small to render available all the water of the district; but the extremely unfavourable nature of the sites at disposal rendered it impossible to get greater storage, except at inordinate cost. This water, which was analysed and reported on by Dr Macadam, was found to contain—

Sulphates and Carbonates,	9·62 grains per gallon.
Organic Matter,	·97 „
Hardness,	7°, with faint action on lead.

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The second scheme proposed was to utilise the water of the White Dam Head stream, which had a drainage area of 700 acres, at, however, such a level as only to supply the low-level cistern by gravitation; but the quality of this water was decidedly inferior, as the report stated that "the presence of nitrates in decided traces in water No. 2 denotes the contamination of this water with decomposing organic matter of animal origin, as capable of being derived from cesspools or sewers, and this property, as well as the decided power which this water possesses of acting upon and dissolving lead conduits and vessels to the extent of being thereby rendered poisonous, at once declares it to be unsuitable for town purposes."

The next source reported on was the Whiteadder, which was for the fourth time proposed to be pumped up to a high-level cistern, and led from it to Berwick. The water of this stream was of good quality on the whole, and was reported by Dr Macadam to contain 7·05 grains of inorganic matter, and 1·31 of organic matter, and to be free from nitrates. The hardness was 4¼°, and it had a slight action on lead. Dr Macadam remarked on it, that the organic matter in it was evidently of vegetable origin, and that it might probably be got rid of to a great extent by filtration, but did not recommend it for use if a purer water could be obtained. Part of this contamination was the result of a paper mill which was further up the stream, at Chirnside.

Once more, however, the question of additional supply was quashed, and nothing more was done till the year 1870, when the Local Board decided on adopting the Whiteadder pumping scheme from a point a little above the lowest dam on it, at a cost of about L.9000, and orders were given to proceed with the working plans. Many animated discussions followed on this decision of the Local Board being known, as some people objected to the scheme on the ground that the quality of the water was bad, and who in some cases preferred the testimony of dumb animals to that of the experienced chemist who had reported so far favourably on the quality of the water. One individual averred that the water must of necessity be bad, as his horse, in whose

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good sense he placed great confidence, and which always liked to stop to take a drink whenever occasion offered to do so, declined, out and out, to taste the water of the Whiteadder when crossing through the ford near the proposed point of abstraction. Another inhabitant of Berwick, however, who had equal confidence in the powers of discrimination of his animal, contended that the water must of necessity be excellent, as his horse often threatened to injure itself by the large quantities of Whiteadder water which it always made a point of swallowing every time it crossed the ford. This evidence seemed pretty equal on both sides, and what might have been the result we cannot say, but the question was finally settled by the intervention of the Royal Commission on River Pollution and Water Supply, who happened to visit Berwick at this time.

Professor Franklin, one of the Commission, analysed a sample of the Whiteadder water, and pronounced it unfit for domestic use, upon which this scheme, which had been spoken of no less than five times, was again given up, and this time probably for ever. The water was also analysed by Mr Dewar of the Veterinary College, who reported against it as unfit for domestic purposes, as he stated that the chlorides present argued the presence of sewage matter in far too large a quantity to permit him to recommend its adoption for a water supply.

After a very short interval the Local Board again decided on adopting the extension of the New East Farm scheme, which was very much the same as the one originally proposed in 1862; but this was also in turn laid aside, as the Pollution of Rivers Commission having got samples of water from this proposed source, and also from the spring at the Tweedmouth foundry, which has since been adopted, reported strongly in favour of the latter, whereupon it was at last determined to proceed with this scheme.

The New East Farm water was examined by Dr Macadam again in October 1870, and he found it to contain 17·41 grains of saline and inorganic matter, and 1·23 grains of organic matter and traces of nitrates. The hardness was 10°. He remarks that the water is of second-class quality for domestic

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use. It contains a considerable amount of saline matter in solution, which communicates 10° of hardness to the water, and the proportion of organic matter is rather larger than what is desirable in a water intended for dietetic purposes. At the same time he was of opinion that this water is wholesome, and in the absence of purer and better water, may be advantageously employed for domestic supply.

Then with regard to the water of the Foundry spring, a letter from Mr T. S. Smith, Secretary to the Pollution Commission, says, "I am directed by the Commission to acquaint you that they are strongly of opinion that the quality of the water of Tweedmouth spring, both as regards its wholesomeness as a beverage and its use for washing, is so vastly superior to the unwholesome water obtainable from the present and proposed gathering grounds, that they would strongly advise the corporation to incur the expense of pumping the water of the Tweedmouth spring for the supply of Berwick, and would recommend you to advise the Secretary of State to sanction the loan for that purpose."

Acting on this advice, the Local Board determined at last to adopt this source of supply, and working plans were prepared by Messrs J. and A. Leslie.

The works consist in the construction of two tanks for storing the spring water, one with the top water at a level of 16 ordnance, and the other about 12 feet higher. The upper tank (fig. 1, *a*), which occupies the site of an old sandstone quarry, is 80 × 50 feet, and 7 feet deep, and has the walls on three sides built of dry rubble stones, to admit the water from the springs rising behind the walls, with the wall next the river built of water-tight masonry in cement, with a puddle wall at the back of it.

The lower tank (fig. 1, *b*), which is 70 × 20 feet, and 7 feet deep, has solid walls, like the one last described, and receives the water from several springs which rise at a lower level than those which are stored in the upper tank. An engine and pump, and boiler, with engine and boiler-house (*c d*), complete the works at the Foundry, and a 9-inch rising main conducts the water to the existing High Level Reservoir, which is placed at a level of about 200 ordnance.

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The springs, of which there were several, were estimated to yield 230,000 gallons in the twenty-four hours, and the engine which was intended to work ten hours per day, was constructed so as to raise 61 cubic feet per minute. The height being 178 feet, and the length of track 8145 feet, with a diameter for the rising main of 9 inches, the head to be allowed for friction was 24 feet, found by formula $h=\frac{Q^2 l}{22 d^5}$ which makes a total height of 202 feet, then calculating the horse power required to raise the water to the high reservoir, by the ordinary method $\frac{61\frac{1}{3} \times 202 \times 62\frac{1}{2}}{33{,}000}$ we have a result of 24, and adding a fourth more for loss = 30 H.P. for the engine. It is worthy of remark that the pressure-gauge on the air vessel registers an increase of 10 lbs., which is equivalent to 24 feet of head while working; and when standing still, the pressure is reduced to that due to the statical pressure, namely 178 feet.

The engine (fig. 4), which is non-condensing, and works vertically, was calculated to work with a pressure in the boiler of 40 lbs. per square inch. The piston is 17 inches diameter, and has a 3 feet stroke, and working with a speed of about 200 feet a minute, makes about 35 strokes in that time. The motion is conveyed to the pump by means of a spur-wheel and pinion (*a*), which revolve in the ratio of 3 to 1, and upon the same shaft as the pinion, is keyed the fly-wheel (*b*), which is 11 feet in diameter, and weighs 5 tons 12 cwts; upon the spur-wheel is bolted the counterpoise, to balance the weight of the flange of the pump. The pump is double acting, consisting of bucket and plunger. The diameter of the cylinder or barrel is $18\frac{9}{16}$ inches, and the plunger (figs. 5, 6, 7) is $13\frac{1}{8}$ inches diameter, with a 3 feet stroke, which at one-third of the speed of the engine, will make about 11 strokes per minute. The bucket is of the construction generally used at the Drummore Colliery, with packing consisting of rings of gutta percha (*c c*), about 1 inch square in section, let into grooves cast in the bucket, with passage along behind, which communicates with the water on the upper side of the bucket, by two

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½-inch holes (*d d*), by means of which the packing is squeezed out against the barrel, and keeps it perfectly water-tight. The valves are of the ordinary butterfly kind, and the air-vessel is 14 feet 6 inches high, and 3 feet 6 inches diameter.

The boiler, which was made of ⅜ inch, and with ends of ½ inch plates, is 26 feet long, 6 feet 6 inches diameter, and has a single flue 3 feet 3 inches diameter, with one flue underneath, and one on each side, with a chimney stalk 84 feet high, 7 feet 6 inches square at the level of the ground, and 3 feet 6 inches at the level of the cope. The boiler is fed by a small plunger feed-pump, worked off the end of the piston cross-head, and the water is heated in a tank with the exhaust steam. The engine and pump were constructed by Messrs Riddle & Son, Tweedmouth, and cost L.950. The rising main is 9 inches diameter, and has for the most part turned and bored joints, except where lead and yarn ones were required for special castings or sharp bends, and has four air and four scouring cocks, with a clack valve immediately above the air-vessel, and another half way up the track. There is a branch pipe leading into the low-service cistern, with a self-acting ball-cock, 6 inches diameter, constructed by Messrs Guest and Chrimes, of Rotherham. The pipes were cast by the Birtly Iron Company, and laid by Mr Paterson, contractor, Edinburgh, and cost, when laid, about 12s. per lineal yard. At the upper end of the pipe is a cast iron measuring box, with a trough, having a flap-valve in the bottom, for passing the water direct into the cistern, if required, by means of which the actual work done by the engine can be determined.

By means of indicator diagrams taken a few weeks ago, I was enabled to calculate the amount of work required to raise the water from the lower tank to the high service reservoir, which is as follows:—

The measuring box was 6 feet × 3 feet 3 inches × 3 feet 1⅜ inches, and has a capacity of 60·64 cubic feet. The average of four experiments gave 58·25 seconds as the time required to fill the box, which represents an amount of 62·5 cubic feet per minute.

The area of the plunger of the pump is ·9398 feet, and the

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double stroke 6 feet long. The engine was making 35 revolutions per minute, which represents 11·66 of the plunger, giving a theoretical discharge of 65·73 cubic feet per minute, which shows a ratio between the theoretical and actual of 100 : 95 with a loss of 5 per cent. This represents an amount of work = to 62·5 cubic feet, weighing 3906 lbs. and raised 202 feet high, which is equal to an expenditure of 23·9 horse power.

The indicator diagram showed an effective pressure of 23 lbs. per square inch, which with 35 strokes per minute at 6 feet, with a piston of 224·5 square inches, is = to 33 horse power, showing a loss for friction, &c., of 27 per cent.

From some notes which I have of the amount of coal burnt, and the price of the different kinds of coal, we find that the result in money per horse power is very nearly the same in each—

Broomhill Nuts,	at	6/6	per ton,	burns	3·7	cwts. per hour	= 1/2½	₱ horse power of engine.
Berwick Hill,	at	9/6	„	„	2·5	„ „	= 1/2¼	
Scremerston	at	9/6	„	„	2·7	„ „	= 1/3½	

Comparing the cost with the actual quantity of water raised, which is equal to an expenditure of 24 H.P.

						Per H.P. per hour.
Broomhill Nuts,	3·7 cwts.	= 17·3 lbs.	per horse power per hour,	=	·602d.
Berwick Hill,	2·5 „	= 11·7	„	„	=	·586d.
Scremerston,	2·7 „	= 12·6	„	„	=	.631d.

If we compare the expense of working this engine with some of the larger ones in use at some of the English water-works, and use the same standard, viz., the cost of raising 1000 gallons 100 feet, which is equal to 1 million foot lbs., we find—

The Trent Water Works Company at Nottingham, cost	·287d.
Bolton and Watts (29 H.P.) 1809 condensing, .	·543d.
„ „ (30½ H.P.) „ „ . .	·358d.
„ „ (76 H.P.) 1828, „ . .	·333d.
Berwick Pumping Engine, 1871, (high pressure). .	·340d.

These works which were formally opened by the Mayor last October, were in use from that time till the end of December, but as the existing sources promised to yield a

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sufficient supply for the inhabitants during the winter months by gravitation, the pumping will not be resumed until that supply begins to fail; and if other towns had, like Berwick, to depend on pumping for their supply of water, when every gallon of water pumped up and then wasted is represented by so much coal, and therefore by so much money thrown away, there would not be such a continued outcry for superabundant supplies of water, nor would that much-prized element be so systematically permitted to run to waste down the drains, with the amount of indifference, not to say approval, that it now so frequently does.

On a New Tool-Holder for the Slide-Rest.

By E. Elmslie Sang, C.E.*

With the means ordinarily in use for securing the cutting-tool to the slide-rest of a lathe, considerable trouble is caused by the want of a ready means for adjusting the height of the cutting point to suit the work that is in progress.

In the examples which I have placed on the table, no provision whatever is made for raising the tool except by placing raising pieces or packing under it, for which purpose the nuts serving to keep the tool in its place have, every time that a change in height is needed, to be unfastened, thereby causing a loss of time, and often considerable annoyance, as it is almost impossible to place the tool exactly over the spot in which it had been before, so that the zero of the new position of the cutting-point has to be found anew.

There are at present several contrivances for getting over this difficulty. One, and so far an excellent one, is to place the slide-rest on a vertical slide, which enables it to be raised or lowered to suit the requirements of the case. Another method is to have the upper slide of the slide-rest hinged, and that part of the slide-rest is lowered or raised by means of a screw or wedge. This attains the end sought, though not so satisfactorily as the first-mentioned contrivance.

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* Read before the Society, 22d January 1872.

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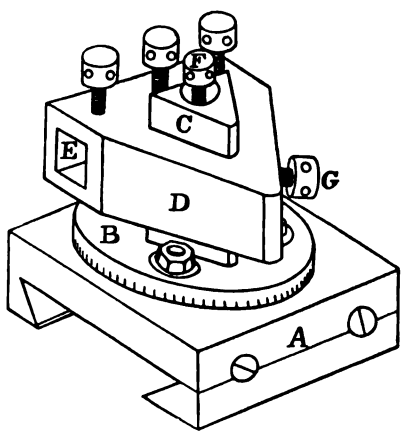
These two examples typify the contrivances which are in use for adjusting the height of the tool.

There is another fault also found in most slide-rests. The tool is secured directly to the top of the upper sliding plate, and thus that plate is inevitably bent, causing it to bite the lower slide on which it travels, so that greater force has to be applied to the feeding-screw to move the slide along, with the consequent effect of soon using up the nut and spoiling the screw. This difficulty is often overcome by relieving the side-tempering screws of the slide, and allowing more play between the bearing surfaces, the result being the production of imperfect work.

The improvement which I now submit to the consideration of the Society is an attempt to remedy these defects. On the ordinary upper plate A of the slide-rest, a circular ⊥ grove is turned for bolts to work in, for the purpose of fixing a round plate or turn-table B. From this turn-



table, a prism C projects of such a length as to suit the variety of work or the raising pieces that are generally used with the lathe. On this prism there is fitted a piece D, which may be called the tool-holder, with a horizontal square hole E, of sufficient size to admit the largest turning tools that may be required, the tool being secured in the hole with binding screws in the usual manner. This tool-holder is kept at the proper height by means of a screw, F,

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working in a projection from the tool-holder; a vertical hole being made down one of the faces of the prism for this projection to pass through, the point of the screw bearing on the bottom of this hole. It is best to keep this supporting screw as near to the tool as possible. By turning this screw F, in or out, the tool is raised or lowered at pleasure; and when adjusted to the required height, the holder is fixed in position by means of a binding screw G at the side. It will be seen that by this arrangement the upper sliding-plate is never bent, however securely the tool may be fastened, as the bolts which work in the ⊥ grove merely bind together two flat surfaces. Then the tool may be moved horizontally to any required position without disturbing the height, or the height may be altered without otherwise disturbing the position of the tool. For the purpose of recording as well as assisting in placing the tool horizontally, the edge of the turn-table is graduated.

On Colour and Colour Sensation. By JOHN AITKEN, Darroch, Falkirk.*

PART I.—COLOUR.

As the subject of the present paper is of a somewhat special character, I have to ask your indulgence while I make a few preliminary elementary observations for the benefit of those who have not yet approached the subject. A beam of ordinary white light is, so to speak, a bundle of rays of different rates of vibration, or, as it is generally called, of different colours. When this beam of white light is passed through a prism so as to form the prismatic spectrum, these rays are separated according to their different rates of vibration—those of slow rate of vibration at one end, and those of quick rate of vibration at the other end of spectrum. The bundle of rays which formed the white beam is broken up into its component colours. These rays are also separated when white light falls on what are called coloured substances, these substances have the power of reflecting only

* Read before the Society, and experimentally illustrated on 12th February 1872.

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rays of certain rates of vibration or colour, whilst the rays not so reflected are probably converted into some other form of energy. If the rays not reflected by coloured substances were added to the reflected rays, the substance would appear white. The light reflected by coloured substances is white, light minus certain rays or colours not reflected. The different rays in white light may also be separated by passing the beam of white light through transparent coloured media —these media have the property of passing only rays of certain rates of vibration or colour, and stopping others. The colour of many substances, which are not transparent in the ordinary sense of the word, is partially due to this cause—the light penetrates a short distance under the surface and is there reflected through a certain thickness of the substance. But that this is not the true explanation of the selective action of all coloured substances, is proved by the fact, that many substances, among which may be mentioned some of the aniline dyes—reflect colours nearly complimentary to those they transmit.

When we wish to colour or paint surfaces, there are two ways of proceeding—we may either use opaque or transparent pigments. If the surface to be coloured is dark, and we wish to give it a bright colour, opaque pigments must be used, and the colour produced is the colour reflected by the pigment employed. But in using transparent pigments the case is very different—they are generally employed for colouring white surfaces. The white surface reflects rays of all the different colours, and when a transparent pigment is spread over it the pigment only allows some of the rays or colours to pass through it and stops others; it acts on the white light like a transparent coloured medium—the light passing twice through it, once before and once after reflection from the white surface underneath. So that in colouring a white surface by means of transparent pigments we act by stopping some of the rays which the white surface formerly reflected. If after having coated the surface with one pigment we coat it with a different one, more rays are stopped out; and if the colours of the pigments are properly chosen, no light will be reflected from the white surface after

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a very few pigments have been used. This explains the reason why, in water colour painting, the colour ought to be produced with one wash, because if a second wash of a different colour is used, much light is unnecessarily stopped out, and the brilliancy of the colour destroyed.

It is from not understanding this selective action of transparent pigments that many people think, that because green is produced by mixing yellow and blue pigments, that therefore green is a compound of yellow and blue, whereas the correct explanation is, that the yellow pigment passes the red and green rays and stops the others; and the blue passes the green, but stops the red passed by the yellow, both pigments allowing the green rays to pass through them from the white surface underneath. The two pigments act, not by mixing the colours *reflected* by them, but by both allowing certain rays to pass by transmission through them. If the rays *reflected* by the yellow and blue pigments are mixed, the result is not green, but is a sort of neutral colour. Here is a mixture of yellow and blue dry paint; under their present circumstances the light does not pass through them, their selective action for transmitted light does not come into play, as they are not at present transparent, but their reflected yellow and blue rays are allowed to mix, and you see the result is not green, but a sort of grey, which is a badly illuminated white. When we add transparent coloured pigment to transparent coloured pigment, we strike down the rays, reducing the brightness; whereas, when we add coloured ray to coloured ray, we increase the brightness. The one is the opposite of the other. The one tends to produce deeper colour and darkness, the other tends to produce whiteness and light. I cannot better explain this than by refering to Diagrams, No. 1 and No. 2.* No. 1 shows what takes place when pigment is added to pigment. In No. 2, I have attempted to represent what takes place when coloured ray is added to coloured ray. In Diagram No. 1 the three circles are painted with yellow

* The diagrams referred to were coloured. In those accompanying the paper, the colours are indicated by their initial letters, the colours being red, green, violet, yellow, blue, and purple.

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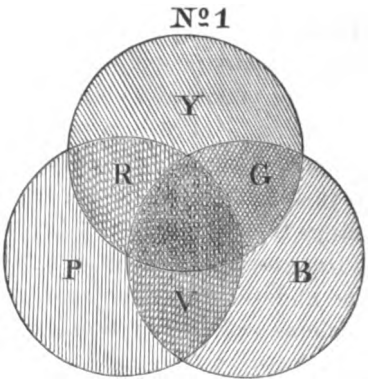
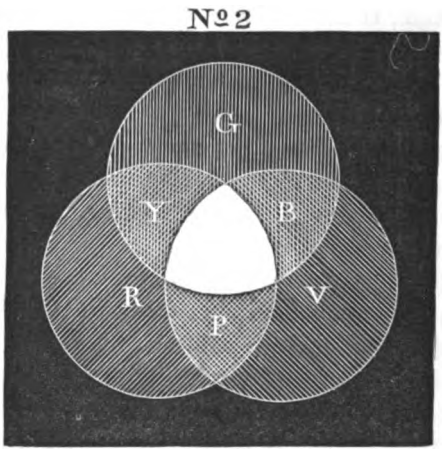
blue and purple, and you will observe that wherever one pigment overlaps the other, the colour is changed and made darker, and where the three colours overlap, it is nearly black, the colour of the centre being due more to the light



reflected by the pigments, than to what passes through them. In Diagram No. 2 each circle represents rays of each of the primary colours;* wherever two of these overlap and the



rays are mixed, the colour is changed and brightened, and in the centre, where the three circles overlap, it is white.

*We may imagine these rays coming from three separate sources, and falling on a surface capable of, but not reflecting any other rays.

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When using pigment, we added light coloured pigment to light coloured pigment, and produced darkness. When using coloured rays, we added dark coloured rays to dark coloured rays and produced light.

I have spoken of pigments being either opaque or transparent. But no pigment is perfectly opaque or perfectly transparent. The most opaque pigment allows some rays to pass through it when thin enough, and the most transparent pigment reflects some rays from its surface. You will therefore understand that in mixing pigments, some allowance must be made for their not being perfectly opaque, or perfectly transparent.

Primary and Secondary Colours.—Early writers recognised two classes of colours—simple or elementary, and compound, or primary and secondary colours. In the first class they placed all colours which could not be analysed into any other colours. In the second they placed those which were compounded of the primaries. This division of colours has been objected to, because in the prismatic spectrum there are no compound colour—all are equally pure. Yet there is reason for this division being retained; because there is this marked distinction between the colours, that whilst certain colours cannot be produced by mixing rays of different parts of the spectrum, yet other colours may be so produced. For instance, red can only be produced by the red rays, while yellow can be produced by the yellow rays, or by mixing red and green rays, or by mixing any rays between the red and green in proper proportion.

Red, yellow, and blue were at first supposed to be the primary colours; but later writers, amongst others, Thomas Young, Sir John T. W. Herschel, and Professor Clerk Maxwell, have shown that yellow is not an elementary colour, but is compounded of red and green, and further, that green is not a compound but an elementary colour, so that the three colours which at the present time are considered to be elementary are red, green, and blue. And it has been shown that white light is produced by mixing rays of these three colours, and also that the secondary colours are produced by mixing two of these colours in proper proportions.

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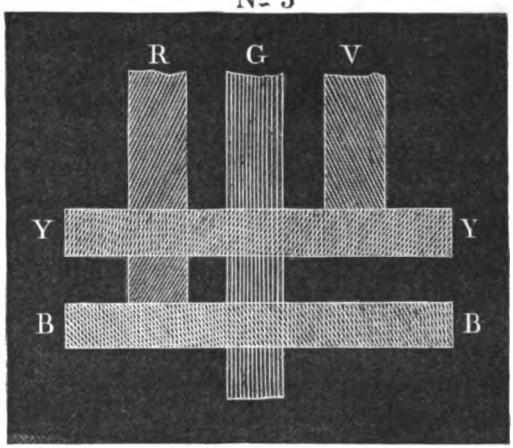
If there are only three primary colours, and these are red, green, and blue, how are we to account for violet? When the light from violet-coloured substances is examined by means of a prism, it is found to be uncompounded. Are we then to rank it as a primary along with red, green, and blue, and so make four primary colours? Red and green have been shown to be elementary, but is blue an elementary colour? A moment's consideration of the fact that a mixture of yellow and blue transparent pigments produces green, is sufficient to show that blue is not an elementary colour. Because, suppose R, G, and V, in diagram No. 3, to represent rays of the three primary colours, which, when combined produce white light. Let Y and B represent screens of

Nº 3



yellow and blue glasses or transparent pigments. Supposing the three primary colours to be red, green, and blue. When rays of these three colours fall on the yellow, the yellow screen will pass the red and green rays, yellow being a compound of these colours, but will be opaque to the blue; and when the red and green rays which passed through the yellow screen, fall on the blue screen, they will be unable to pass through it, if blue is a primary colour. No light could come through such a combination of coloured screens. But instead of this being the case, the green rays which passed through the yellow screen, also passes through the

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blue screen; that is, the blue screen is transparent to the green rays, and therefore blue is a compound of green and some other rays, in the same way as yellow is also a compound of green and other rays. While the yellow stops certain rays and the blue stops others, yet both the yellow and blue screens pass the green rays. In order to be further satisfied on this point, a great number of blue substances were procured and examined by means of a prism, and in every case it was found that green entered largely into the composition of the blue; and along with those green rays were mixed the rays of the violet end of the spectrum. Blue is therefore a compound of green and violet; or, to state it more correctly, blue substances reflect the rays of the spectrum from the green to the violet. They not only reflect pure blue rays, but they also reflect the green and violet rays. In the same way as yellow substances reflect red and green rays along with the pure yellow rays.

The best manner of examining the compound nature of the rays reflected by blue substances, is the following:— Take a narrow stripe of white paper, say one inch broad, paint two-thirds of its breadth with blue, then paint one-half of the blue over with yellow, so as to produce a green; there will thus be produced a band which has a stripe of white at one side, one of blue in the centre, and one of green at the other side. Now examine this band by holding a prism so that its reflecting angle shall be at right angles to the length of the band, when spectra somewhat like the following will be seen:—On the one side is the spectrum of the white paper, having rays of all the different colours; next is the spectrum of the blue, having the green and violet rays, the red having been struck down by the blue paint; on the other side will be seen the spectrum of the green having only the green band, the yellow pigment which was painted over the blue having struck down the violet rays. Now pass the eye along the green bands of the spectra, from that of the white through that of the blue to that of the green, when it will be seen that though the green band given by the blue stripe is not so bright as the green of the white, yet there is no apparent difference between the brightness of the green band

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of the blue, and that of the green, showing that there is as much green in the blue as there is green in the green stripe. From this experiment, we see that the brilliancy of the green produced by mixing yellow and blue transparent pigments is the measure of the transparency of the blue pigment employed to the green rays. If blue was not a compound colour, any mixture of yellow and blue transparent pigments could not produce green. Because, if blue is an elementary colour, we have shown that a mixture of yellow and blue pigments would form an opaque combination. The colour produced by such a mixture would depend on the rays *reflected* by the substance of the coloured layers themselves, not on the rays *passed through* them from the white surface underneath.

Blue has thus been shown by analysis to be compounded of green and violet; and since blue can be analysed into these colours, a mixture of green and violet rays ought to produce blue. I have here an experiment to show that blue is produced when the green and violet rays of the prismatic spectrum are combined.* Inside this lantern is placed a source of light, the sun or the electric light would have given the best results. In the present experiment we have only the lime light, the light from the lime cylinder is passed through a slit, focused by a lens and passed through a bisulphide of carbon prism in the usual way. The spectrum is allowed to fall on a large number of small rectangular mirrors placed close to each other. All the mirrors receive and reflect rays of different colours. Each mirror is moveble round an axis, so placed that the mirrors can be set to throw all their reflections on one spot in the centre of the screen in front of you. At present all the rays of the spectrum are allowed to fall on the mirrors, and are reflected to the one spot, where they are recombined to produce white light. The prism broke up the beam of white light into all its colours, the reflectors have again combined these colours and produced white light. By the arrangement of

* This experiment was not made, owing to the short time given for reading the paper.

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our apparatus we can stop any rays from falling on the reflectors, and allow only certain rays or colours to combine. I now place in front of the mirrors one large mirror, which reflects the whole spectrum on to another part of the screen, a little above the spot where all the rays were formerly combined. I shall now move the large mirror gradually along the spectrum, so as to allow the rays at the red end of the spectrum to fall on the small mirror. These rays are now reflected to the spot in the centre of the screen, and you see a dull red spot, and as I continue to move the large mirror in the same direction more red rays fall on the small mirrors and are reflected to the same spot as the other red rays. The spot is brightened. It now seems to glow like a piece of red-hot iron; and as I continue moving the large mirror in the same direction, the other rays of the spectrum are added to the red, and now the spot appears yellow, and you will observe that the spectrum above the spot—which, when we began the experiment, contained all the colours—has now only part of the green and the whole of the blue and violet, the rest of the green and the red being combined by means of the small mirrors to form the yellow spot. As we continue moving the large mirror in the same direction, it reflects fewer and fewer of the rays. Those not reflected by it are reflected by the small mirrors; and you will observe, that as the rest of the green, the blue, and violet rays are added, the one after the other, to the yellow, the yellow changes gradually to white. You will have observed the likeness of the centre spot on the screen to a solid body which is being heated,—at first dull red, then bright red, and as the heat rises the red changes to yellow, and last of all to white. The body, when being heated, at first only sends out red rays, or rays of slow rate of vibration; as its temperature rises, the rate of vibration increases, and along with the red rays it sends out green rays; these, when combined with the red rays, make the body appear yellow. When the temperature of the body rises still higher, it sends rays of still quicker rate of vibration; these combining with the yellow, produce white, in the same way as we saw the spot on the screen change to yellow when the green

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rays were added to the red, and to white, when the violet rays were added to the yellow.* In this experiment, as all the rays of the spectrum are reflected on to the screen, those which were not combined on the centre spot are in the spectrum above it, we can thus see at a glance what colours would be necessary to be added to the colour of the centre spot to produce white. And if we place another large mirror in front of the small mirrors, which are reflecting rays to the centre spot, we will see reflected on the screen all the rays or colours which, when combined, produced the colour of the spot.

I have said in a former part of the paper, that though all the rays of the spectrum are equally pure, the yellow of the spectrum is as much a pure colour as the red; it contains nothing but yellow, yet there was this difference, that while some colours could be produced by mixing rays of some other colours, there were others which could not be so produced. For instance, yellow may be produced by mixing red and green, but neither the red nor the green can be so produced. I shall now illustrate this by means of this apparatus: I place two large mirrors in front of the small ones; the junction of the mirrors is now at the green part of the spectrum; drawing the large mirrors slightly apart, the green rays fall on the small mirrors and are reflected to the spot in the centre of the screen, and the green band is absent from the spectrum above the spot. If I now draw the large mirrors further apart, so as to allow the rays on each side of the green to be combined with the green on the centre spot, you will observe the green changes in appearance,—it is no longer a rich green, but a mixture of green and white. Now, putting the junction between the large mirrors at the red part of the spectrum, and separating them so as to allow the red rays to fall on the small mirrors, and we get a red spot on the screen. If I now draw the large mirrors further apart, so as to allow the rays on each side of the red to combine with the red rays, you see the red spot changes in

* It is difficult to get the spot in the centre of the screen quite white, in this experiment, our source of light being rather deficient in rays of the violet end of spectrum.

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colour; at first it is tinged with orange, and as more rays are added it changes to yellow. The violet part of the spectrum is also changed in the same way, although this is more difficult to show on account of the darkness of the violet. The violet rays are now falling on the centre spot, and as I add the rays on each side of the violet, it gradually changes to blue. But now let us put the junction between the large mirrors over the yellow, and separate the mirrors. so as to allow the yellow rays to fall on the small mirrors. We have now a yellow spot on the centre of the screen, and the yellow band is absent from the spectrum above it. I now draw the large mirrors further apart, and the rays on each side of the yellow are being reflected on to the centre spot and combined with the yellow, but you see no change in the colour of the spot, it is only brightened, and now I have drawn the large mirrors so far apart, that the spectrum above the spot contains no red, and but little green, and yet the spot is the same colour as it had at first,—the red and green rays when mixed producing the same colour as the pure yellow rays. We shall now move the junction between the large mirrors to the blue part of the spectrum, and separate them so as to allow the blue rays to fall on the small mirrors, and we have now a blue spot on the screen; and as I separate the mirrors further apart, the rays on each side of the blue are also being reflected to the centre spot, but you see no change in colour of the spot, it is only brightened. I have now drawn the mirrors so far apart that the whole of the violet is thrown on the centre spot, and there is only part of the green in the spectrum above the spot, the rest of the green being combined with the violet on the blue spot. The amount of green which combines in this case with the violet is not great,—the reason being that our source of light is deficient in violet rays. When the sun-light, which has a greater abundance of violet rays, is used, a greater breadth of the green band requires to be added to the violet to produce blue. By these experiments we have seen that some colours can only be produced by certain rays whilst other colours can either be produced by certain rays, or by combinations of other rays. We have also seen that blue can be produced by mixing rays of other colours, and that the violet cannot be

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so produced. The violet, therefore, ought to be classed as a primary, and blue as a secondary colour.

Blue may also be produced by combining green and violet in another way. Here are two discs of paper, one coloured green, the other violet. These discs are slit along a radius so as to admit of being slipped one over the other, to enable us to expose varying proportions of the two colours. I now cause the discs to rotate rapidly by means of mechanism placed behind these discs, and you see that when the green and violet are mixed in the proportions we have at present, a very good blue is produced, and by varying these proportions we can get any colour from green through blue to violet. I shall now show you, by means of these discs, the colours produced by combining the violet with the red in varying proportions, and you see there is produced a series of colours much richer and purer than when blue is combined with red. The green in the blue combining with the red and violet has the effect of diluting, so to speak, the colour with a large proportion of white light.

You are aware we can produce any colour by means of these rotating red, green, and violet discs, by mixing these colours in the proper proportions. I have now to show you an addition to this instrument, which I think will be found useful to those studying colour. The object of this addition is to produce the shades and tints of the colours. This may be done by using white and black discs along with the coloured discs,—mixing white with the coloured discs to produce the tints, and black to produce the shades. But as it would be extremely troublesome to keep always the same proportions of the different colours when increasing or diminishing the white or black, I prefer, therefore, to adopt the following method. In front of the coloured discs is placed another cardboard disc, having a number of openings cut in it, in the manner you see, to expose the coloured discs underneath. At a radius halfway between the centre and the circumference of the disc the whole of the cardboard is cut away, except so much as will carry the outside part of the disc. On each side of this radius less and less of the cardboard is cut away, and at the centre and circumference there is none cut out. The outside part is blackened, the

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inside is kept white. When this disc is placed in front of, and rotated with the coloured discs, you have, at one and the same time presented before you the colour produced by the coloured discs, all the shades of that colour, and all its tints. At a radius half-way between the centre and the circumference, where all the cardboard is cut away, you have the full colour—towards the centre you have all the tints produced by mixing varying proportions of white with the colour—towards the circumference you have all the shades produced by mixing the varying proportions of darkness, if I may use the expression, with the colour. This is an extremely convenient way of studying the shades and tints of the different colours, as they are all presented before us at the same time, and may be easily compared the one with the other. This way of producing the shades and tints is open to the following objection, that each of the colours on the discs can only be combined in certain proportions to give correct results. There must be as much of each coloured disc exposed as will fill either one-half, or some multiple of a half, of an opening in the front disc. If desired, an instrument could easily be made to overcome these objections. If we cause the front disc to rotate at a different speed from the coloured discs, then the colours on the discs may be combined in any proportion we may desire, and the front disc will give the shades and tints correctly.

In a recent work on colour, I find the following table of prismatic colours.

TABLE OF PRISMATIC COLOURS.

Red Band.....	Dark Red.
	Bright Red.
	Yellow Red or Orange.
	Yellow.
Green Band.....	Yellow Green.
	Green.
	Sea-green Green.
	Sea-green.
Blue Band.....	Sea-green Blue.
	Blue.
	Dark Blue.
	Very dark Violet.

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In this table blue is one of the primary colours; and in order to keep the same number of secondary colours between green and blue as there is between green and red, there are introduced, sea-green green, between the green and the sea-green, and sea-green blue, between the sea-green and the blue. But to most eyes there is not the same difference between, green, sea-green green, seagreen, sea-green blue and blue, as there is between green, yellow-green, yellow, orange, and red, or as Professor Clerk Maxwell, when speaking of the colours on each side of the green, says, "This division of the spectrum is by no means a fair one. Between the red and the green we have a series of colours, apparently very different from either, and having such marked characteristics that two of them, orange and yellow, have received separate names. The colours between the green and the blue, on the other hand, have an obvious resemblance to one or both of the extreme colours, and no distinct names for these colours have ever become popularly recognised.*" I have therefore to propose for the reasons which I have given, that this table of prismatic colours be changed and blue put in the place of sea-green and violet in the place of blue. The table will then stand as follows.

Table of Prismatic Colours.

In order to save space, the numbers of the undulations given in the table are the numbers divided by 1·000, 000, 000, 000.

Red Band.....	Dark Red	458	19
	Bright Red	477	29
	Yellow-Red or Orange	506	29
	Yellow	535	20
Green Band.....	Yellow-Green	555	22
	Green	577	23
	Blue-Green or Seagreen	600	22
	Blue	622	36
Violet-Band.....	Blue-Violet or Indigo	658	41
	Violet	699	28
	Dark Violet	727	

* "Nature" May 4. 1871.

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In this table as re-arranged we have now well-marked colours on each side of the green, though the difference is not so great on the violet side of the green as on the red side, yet we have one colour between the green and the violet, namely blue, which has received a separate name and become popularly recognised. There is one point which seems to support the idea that there is the same difference between the colours from green to violet as there is between the colours from green to red, which is this. As our sensations of the different colours are produced by the different numbers of undulations per second which fall on the retina of the eye, we would expect that if there is the same difference between each succeeding and preceding colour in the table, that there would be the same difference between the numbers of their undulations. Opposite each colour in the table I have marked the number of undulations which the pure rays of these colours make per second. To the right is marked the difference betweeen them, or the increased number of undulations per second, made by the succeeding over the preceding colour, and it will be observed that for colours near the centre of the spectrum, there is very nearly the same difference between the number of undulations of each preceding and succeeding colour, and it is only near the ends of the spectrum that the difference changes and becomes greater, as might be expected, on account of the limits of the sensibility of the eye being nearly approached by the number of vibrations made by the rays at those parts. When this test is applied to the other table, we find that the difference of rate of vibration of the pure rays of the colours from green to blue is only about one-half of what it is for the colours from green to red.

Part II.—COLOUR SENSATION.*

To those begining the study of colour, the subject seems, if not one of great difficulty, to be enveloped in considerable confusion. To them the terms pure rays, compound rays, compound colours, compound sensations, &c., convey no very

* Read before the Society on 9th July 1872.

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clear ideas. This confusion greatly arises from our knowledge being confined to the sensations themselves and to the rays which produce these sensations, whilst the means by which these sensations are produced are but little understood. When a ray of light of one rate of vibration falls on the nerves of the eye, it produces one sensation; when a ray of a different rate a different sensation is produced. Whereas, when a ray of heat falls on the nerves which are capable of being affected by it, the same sensation is always produced, whether the ray has a quick or slow rate of vibration—the only thing it can distinguish is the intensity of the heat. How then is it that the eye is not only differently affected by the different intensities of the light, but also by the different rates of its vibrations. The theory which gives the best explanation of these phenomena is, that the sensations produced by light, and which we call colour, are not simple, like our sensation of heat, but are compounded of three different sensations; and according to most writers on the subject there is a great probability that there are three sets of nerves in the human eye corresponding to these three sensations. As this three-nerve theory seemed to give such a satisfactory explanation of most of the phenomena of colour, I think a clear perception of the probable action of these nerves will remove much of the difficulty experienced in the study of colour, I have therefore ventured to bring the subject before you, along with some experiments suggested by this theory. These experiments I think may to some extent be accepted as proof of the theory. Before bringing this theory before you, I shall state some reasons for supposing that there are more than one set of nerves in the eye. If there is only one set of nerves in the eye, we should expect these nerves to be arranged according to one plan; and while we could imagine these nerves so arranged, that when two rays of light, of different rates of vibration, fall on the eye, they would produce the same sensation as a ray whose rate of vibration was a mean betweeen the two. With the eye we find this to be nearly the case only with rays at the ends of the spectrum, but not with rays at the centre. When rays of the rates of vibration of

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the red and the green fall on the eye, they produce the same sensation as the yellow ray, whose rate of vibration is a mean between the rates of vibration of the red and green, but when the yellow and blue rays fall on the eye, the sensation is not green, whose rate of vibration is a mean between that of the yellow and blue, the sensation produced by the yellow and blue rays being nearly white. But it might be supposed that the nerves of the eye were constructed somewhat on the same principle as those of the ear, which are capable of detecting a difference of rate of vibration as well as a difference of intensity ; if so, the mechanism of the eye would be extremely complicated, because it would not be like *an* ear, but like an infinite number of ears. Each point on the retina would require to have mechanism capable of being acted on, and conveying all the different impressions produced by the rays of all the different rates of vibration. One reason for supposing that the nerves of the eye are not constructed on the same principle as those of the ear is, that after a loud sound of any rate of vibration has acted on the ear for some time, and suddenly ceases, the sensibility of the ear is alike diminished for all sounds, whether of quick or slow vibratory period. Whereas, after a bright light of one rate of vibration or colour has acted on the eye for some time and suddenly ceases, the sensibility of the eye is only diminished for rays of the same rate of vibration or colour as those which acted on it, but is quite sensitive to rays of all other rates of vibration or colour. This would seem to indicate that there are more than one set of nerves in the eye, and that while one colour of light may fatigue one set of nerves, the other set or sets of nerves may be unaffected.

Sir John Herschel thought there was a high probability of there being three sets of nerves, and he also thought it probable that there were three distinct species of light, each competent *per se* to excite one of the three primary colours. But it is now generally admitted that there is only one kind of light, and the only difference between the rays of the different parts of the spectrum is one of difference of rate of vibration. Admitting the existence of three nerves in the

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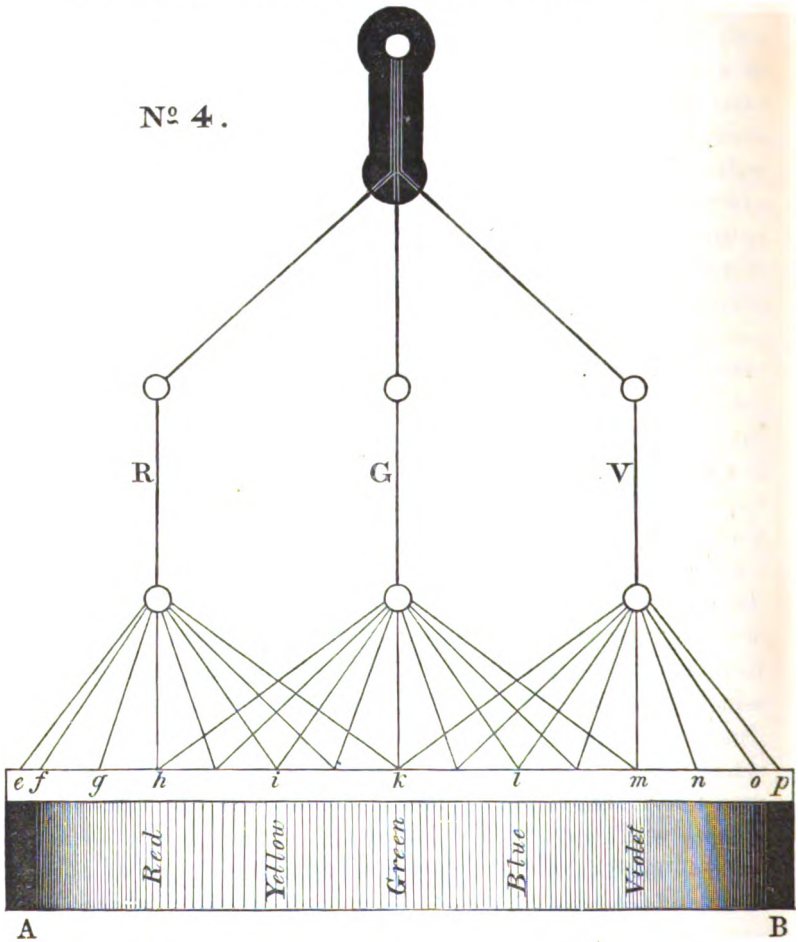
eye, there is no necessity for supposing that there must also be three kinds of light to act on these nerves, as one kind of light; will give a perfectly satisfactory explanation of all the phenomena.

I have been unable to find any account of this three-nerve



theory; the only information I can find is simply the mention of the probability of there being three sets of nerves in the human eye. In diagram No. 4, I have attempted to show what I imagine to be the manner in which, according to this three-nerve theory, all the infinite variety of colour

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sensations are produced, by the action of light on these three nerves. A B represents the prismatic spectrum—along the upper edge are marked the letters, *e f g . . . o p*, representing the rates of vibration of the rays at those parts. Above the points of purest red, green, and violet, are drawn the lines R, G, and V, to represent the nerves, which, when excited, produce the sensations of red, green, and violet, and which for shortness may be called the red, green, and violet nerves. In what follows, I shall repeatedly use the terms red-light, red-nerve, green-light, &c., though there may be objections to their use, yet I think if we use them in the same sense as we use the terms, heat-rays and heat-nerves, there need be no cause of confusion. From R, G, and V, lines are drawn to all parts of the spectrum to which these nerves are sensitive. Suppose, now, a ray whose rate of vibration is *e*, falls on the retina of the eye, it is incapable of affecting any of the nerves. The surface from which it is emitted is what we call black, none of the nerves of vision being capable of being affected by rays sent from that part of the spectrum. Yet we know by other means than the eye that there are rays in that part of the spectrum of much greater energy than those which are capable of affecting the nerves of the eye. Now suppose the ray whose rate of vibration is *g* falls on the eye, it is capable of exciting the red nerve, which produces the sensation of redness, but is incapable of exciting any of the other nerves. As the rate of vibration increases, the sensitiveness of the red nerve also increases, till it reaches its maximum sensitiveness to luminous vibrations, when the rate of vibration is *h*. As the rate of vibration increases the sensitiveness of the red nerve decreases till it is quite insensible to rays whose rate of vibration is greater than *k*. The green nerve, again, is not excited by any ray of slower rate of vibration than *h*, it becomes more and more sensitive as the rate increases, attaining its maximum sensitiveness when the rate is *k*, and becomes less and less sensitive as the vibrations are quickened, till it becomes insensible to rays of quicker rate of vibration than *m*. So with the violet nerve, it becomes excited when the rays vibrate at the rate *k*, most excited

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by rays of the rate *m*, and becoming insensible to all rays of quicker vibration than *o*. As you are aware, this is somewhat similar to the action of the nerves of the ear. If the number of sound vibrations falls below a certain number per second they cease to give a sound, and if they rise above a certain number per second, they are incapable of affecting the nerves of the ear. This diagram represents what we might imagine to be the action of a perfect eye. In all probability, in most eyes the limits of the sensitiveness of the different nerves are not so well defined nor so equally spread over the spectrum. For instance, it is very possible that in some eyes the green-nerve, say, is sensitive to rays whose rate of vibration is *g*; its sensitiveness may also extend further into the violet than the point *m*. The same with the other nerves,—they also may extend more or less than shown. It is extremely difficult to tell, for any particular eye, at what points the different nerves begin to be sensitive, and at what points they cease to be sensitive, owing to an action of the eye on itself, which shall be considered afterwards. We will therefore look on this diagram not as representing the action of any individual eye, but as a type to which most eyes approach more or less closely, and which is greatly departed from in colour-blind eyes.

So far we have only considered the sensation produced when one nerve is excited. Suppose, now, that two nerves are excited, the sensation becomes a compound of the two sensations. If the red and green nerves are excited, the sensation is what we call yellow. If the green and violet nerves are excited the sensation is blue, and if the violet and red nerves are excited the sensation is purple, and according as the one nerve is excited more or less than the other, the compound sensation inclines more or less towards the sensation of the nerve most excited. For example, when rays of the rates of vibration of *h* and *k* fall on the eye, the sensation of yellow is produced; again, when a ray of the rate of vibration of *i* falls on the eye the sensation is also yellow, because both the red and the green nerves are equally excited by that ray. But supposing a ray whose rate of vibration

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is intermediate between *h* and *i* falls on the eye, then the red nerve will be more excited than the green, and the compound sensation will incline towards the red, and will be what we call orange, which is nearer the red sensation than the green.

We see how it is impossible, according to this theory, to analyse by means of a prism the pure yellow rays of the spectrum into red and green. Because the prism acts on the rays of light by separating these rays according to their different rates of vibration; and it does not matter through how many prisms the pure yellow rays are sent, they will always have the same rate of vibration, and will therefore be able to excite both the red and green nerves. According to this view the pure yellow rays produce a compound sensation—as much a compound sensation as the sensation of yellow produced by mixing red and green rays. In both cases the red and green nerves are excited. Again, when the three nerves are excited in certain proportions, the sensation of white is produced, and if one of the nerves is excited more then the others, the sensation will incline towards the sensation of the nerve most excited, and the light will be what we call tinted with the colour or sensation of the nerve most excited. This theory also gives an explanation of the reason why the primary colours are dull, secondary colours brighter, and white light brightest of all. Suppose a ray of the rate of vibration of any of the primary colours, say *k*, to fall on the eye, the sensation is green; but if the rays on each side of *k*, of quicker and slower vibration than *k*, also fall on the same point of the retina, they produce the sensation of green, but they also produce the sensations of red and violet; these combining with the green produce a compound sensation, which changes from green to a green more or less mixed with white. The same is the case with the red and violet—if rays on each side of *h* and *m* are mixed the sensations are changed. There are but few rays in a beam of white light which only excite one set of nerves; all the other rays which excite the one set of nerves also excite the other set or sets of nerves, making the sensation compound. The extent to which one nerve can be excited

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alone is therefore small, and the sensation or brightness small.

We shall now consider the case of the secondary colours. Suppose we take yellow. When a ray whose rate of vibration is i falls on the eye, the red and green nerves are excited; but all the rays from h to k are capable of exciting these two nerves, so that when the rays on each side of i of quicker and slower vibration are mixed the sensation is not changed, but is only intensified—both nerves continue to be excited in the same proportions—the sensation is bright yellow. Indeed, we may mix the rays of slower vibration than h and quicker than k and still produce yellow, taking care that we do not mix rays of quick enough vibration to excite the violet nerve to any extent. The brilliancy of the primary colours is the effect of but a few of the rays; the brilliancy of the secondary colours may be the effect of about one-half of the rays, and the brilliancy of the white is the effect of all the rays capable of affecting the eye.

We have, then, by this theory, three sets of nerves producing three simple sensations. The only thing we can distinguish by these nerves *separately* is *intensity*. The red nerve only gives us the sensation of red in a greater or less degree, the green nerve only the sensation of green, and the violet nerve only the sensation of violet. The sensation produced is the same, whatever may be the rate of vibration of the rays, provided the nerve is sensitive to them, the only difference the nerve can detect is the intensity of the rays. Each set of nerves in the eye are similar to our heat nerves, capable of detecting only intensity. If we had only one set of nerves in the eye, we could only have one kind of sensation when light falls on the eye, and the light from different objects would only differ in brilliancy and not in kind. But with three sets of nerves, each giving a different sensation, not only have we these three sensations, but we have an infinite variety of sensations produced by compounding these three simple sensation in different proportions. It might be thought, if this were the case, then we ought to be able to recognise the sensations of red and green in yellow; but a little consideration will show that we are

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not justified in this expectation, because most of our sensations are compound, and it is very difficult, and in some cases impossible, to separate the different sensations. For instance, how compound are our sensations when touching objects. It is extremely difficult when touching cloths, to say how much of the sensation is produced by the hardness or softness of the material, and how much to our sense of heat from the good or bad conducting properties of the material. Looking at the subject of the primary and secondary colours from this point of view, it is our sensations which are simple or compound, and not the light which produces these sensations. The light reflected by all coloured substances is a mixture of rays of different rates of vibration. It does not matter whether the object is coloured green or blue. There may be as much difference between the rates of vibration of the different rays in the green as there is between the different rays in the blue. The light may be a mixture of rays of as many rates of vibration in the one case as in the other. The difference between the two is that the rays of the rates of vibration of the green light are only capable of exciting one set of nerves, and producing a *simple* sensation, while the rates of vibration of the blue rays are such that they are capable of affecting two set of nerves, so giving a *compound* sensation. In the above, the terms red nerve, green nerve, and violet nerve, have been often used; some of you may object to their use, as it has not yet been clearly proved that there are three sets of nerves in the eye. I would ask those who so object to the theory to substitute the word sensation for nerve, and little if any alteration will be required.

The three-nerve theory, as represented in diagram No. 4, seemed to give so very fair an explanation of many of the phenomena of colour, that I determined to put it to the test of experiment. I have said that according to this theory, when the pure yellow ray, whose rate of vibration is i, falls on the eye, the sensation produced is a compound of the sensations of red and green, in the same way as the yellow produced when rays of the rates of h and k are combined. If this be so, I thought it might be possible to prove it. If, for

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instance, we could remove the green nerve, then the ray *i* ought to give the sensation of red, if we remove the red nerve, then it ought to give the sensation of green, now, though we cannot remove one of the nerves, yet if we fatigue a nerve we make it less sensitive, which is the same thing as partially removing it. The sensation from the fatigued nerve being less, the sensation from the other nerve will be proportionately greater, the combined sensations will therefore partake more of the sensation of the unfatigued nerve. I shall now repeat before you the first experiment I made in this direction. I have here two substances, one of which burns with a bright red light, produced by burning strontium, the other produces a green light by burning barium. In this glass cup I have a quantity of common salt (sodium chloride) and spirits of wine, this, as you are aware, when burning gives only the pure yellow rays *i*. In order to have as pure a flame as possible, I have used pure alcohol, and so arranged it that the salt acts as a wick, which will remove the chance of impurity being got from a cotton wick. I shall light the spirit lamp and place it under cover; I shall now light this substance which produces the red light. Before doing so, I have to ask you to close one of your eyes, and place your hand so as to shade, but not so as to press on it. The object of closing the one eye is that you may be enabled to keep it as a standard of sensation, with which to compare the sensation of the fatigued eye. I call your attention to this method of experimenting on only one eye, keeping the other as a standard with which to compare the sensations of the fatigued eye, as I think it will be found useful to those experimenting on colour. Now look steadily at the red light with your other eye till I remove the light, which I shall do when your eye is fatigued. I now remove the red light and uncover the lamp, and ask you to look at the yellow flame with the fatigued eye. Now close the fatigued eye, and look at the flame with the other eye, and note the difference, when I expect, to the unfatigued eye the flame will appear yellow, and to the fatigued eye it will appear yellow-green. I shall again cover the flame, and ask you to close and cover the

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fatigued eye, and look steadily with the other eye at this green light now burning. Your eye is now fatigued. I remove the green light, and ask you to look at the yellow flame, which I now uncover, when I expect the yellow flame will appear yellow-red or orange colour to the eye last fatigued, and when looked at with the other eye, it will likely be still slightly greenish. The sensation produced by the pure ray *i*, which the prism is unable to break up into other colours, is shown by this experiment to be a compound and not a simple sensation. You will observe that this is a very different experiment from the well-known one of first looking at a red object for some time, and then directing the eye to a yellow surface, when a greenish image of the object is seen. In this case the yellow surface reflects red and green rays, so that when the eye is fatigued with red, the green rays produce a greater impression on the eye than the red rays, making the image appear greenish, while, in the experiment just made, we had neither red nor green rays falling on the eye, but only the pure yellow rays *i*. Now there is a possibility that the yellow light from the lamp used might not be quite pure. I therefore fatigued the eye as before, and cast the prismatic spectrum of the sodium flame on the eye, when I found that the yellow band changed colour in the same way as the flame did. When one eye was fatigued with red and the other with green light, the yellow band looked yellow-green to the one eye, and orange to the other. It would seem then, from these experiments, that the pure yellow ray *i* produces a sensation which is a compound of the red and green sensations. I may remark here, that according to this three-nerve theory, a primary colour is a simple sensation, it is the effect of rays of light capable of effecting only one set of nerves. A secondary colour is a compound sensation, it is the effect of rays of light capable of affecting more than one set of nerves. In this sense even the pure ray *i* is a secondary colour, as it produces a compound sensation.

So far the experiments seemed to be in favour of the three-nerve theory. But before drawing any conclusion, it would be necessary to test the sensations produced by the pure

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rays of all the different parts of the spectrum. As it would be impossible to get flames which would give only these rays, I experimented with the rays of the prismatic spectrum in the following manner:—Having arranged apparatus so as to give either the solar spectrum or the spectrum of the lime-light, by passing the light through a slit focussing with a lens, and passing it through a bisulphide of carbon prism, the spectrum was thrown on a screen, in front of which was placed two small mirrors and a strip of white paper, each about a quarter of an inch broad. These mirrors and paper strip were so arranged that they could be moved along in front of the screen, so that rays of any part of the spectrum could be caused to fall on them. About two feet in front of the screen was fixed a board carrying two pairs of eye-holes, the one pair placed a few inches above the other. The two lower holes were open, the two upper were provided with a shutter, which always closed one of the eye-holes; and by moving a handle connected with it, either of the eye-holes could be opened. The following was the method of conducting the experiments. One mirror was placed in, say, the red part of the spectrum, the other in the green, while the paper strip was placed in the yellow. The mirrors were so turned as to reflect the red rays to one eye and the green rays to the other eye, through the lower eye-holes. After looking through the lower eye-holes, till the one eye was fatigued with red and the other with green light, the upper eye-holes were then looked through, and by moving the shutter the yellow strip was looked at first with the one eye, then with the other, and the difference noted. The result was the same as in the former experiment. To the eye fatigued with red, the strip was yellow-green; to the eye fatigued with green, the strip was orange. The blue part of the spectrum was then tried in the same way, when it was found that the blue changed into a blue-green or blue-violet, according as the eye was fatigued with violet or green. In experimenting with this end of the spectrum, it was found to be difficult to fatigue the eyes with the rays reflected from the small mirrors, on account of the darkness of this end of the spectrum. It was therefore necessary to

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adopt some other method of fatiguing the eye. In most of the following experiments the eye was fatigued by looking at a gas flame through coloured glasses. These glasses were carefully selected from a large number, by means of a prism, and the purest chosen.

Now if the three-nerve theory is true, it would at first appear that it ought not to be possible to change to any extent the sensations produced by the *h*, *k*, and *m* rays, because each of these rays is only capable of exciting one set of nerves,—the *h* rays being only capable of affecting the red nerve, the *k* rays only capable of affecting the green nerve, and the *m* rays only capable of affecting the violet nerve,—and therefore each of these rays ought only to be capable of producing one of these sensations. The test was put, one mirror was placed in the yellow, and one in the blue, and the paper strip in the green, when it was found that to the eye fatigued with yellow, the strip looked bluish green, and to the eye fatigued with blue it looked a yellowish green. But the change in the green was not by any means so decided as the change which took place in the yellow and blue in the former experiments. Indeed there was considerable difficulty in telling in what the difference consisted; to the one eye it appeared darker than to the other, and it was difficult to tell how much of the change was due to this cause, even when using a small diaphragm to stop out part of the light from the eye to which it looked brightest, after a considerable number of experiments, the conclusion was that there was a change in colour—to the one eye it looked a blue green, to the other eye a yellow green. But the experiments were so unsatisfactory that another method of experimenting was adopted. Instead of looking at the change which took place in a narrow strip of the spectrum, the change was noted which took place in the whole spectrum. A line was marked in the screen, and the screen made moveable, so that the line could be placed in any part of the spectrum. For instance, the screen would be so placed, that the line would fall on the yellow of the spectrum. The one eye was fatigued with red rays, the other with green. When the space in the spectrum between the red and green was

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looked at with the eye fatigued with red, the part where the line was and which formerly looked yellow, now looked greenish yellow. The green part of the spectrum had extended towards the yellow, the yellow part had moved towards the red, and the red space was darkened and diminished in breadth. When the spectrum was looked at with the eye fatigued with green, the part of the spectrum at the line was orange, the red had extended towards the yellow, the yellow had crossed the line towards the green, and the green was darkened and diminished in breadth. The point to be noted here is, that not only was the part which formerly looked yellow changed to yellow green, and orange, but that the yellow part of the spectrum had changed its position—in the one case nearer to the red in the other case nearer to the green. The reason for this, according to the three-nerve theory is, that supposing one eye to be fatigued with red, then when the ray *i* falls on the eye, it cannot excite the red nerve so strongly as the green, the green sensation will therefore predominate; and in order that the two sensations may be produced in equal degrees to give the yellow sensation, some ray must fall on the eye of slower rate of vibration than *i*, capable of affecting the fatigued red nerve more, and the green nerve less. The same experiment was then made with the blue part of the spectrum. The line in the screen was placed in the blue. The one eye was fatigued with green, and the other with violet; when the space between the green and the violet was looked at with the eye fatigued with green, the green was darkened, the violet extended towards the green, and the blue crossed the line to a point nearer the green; and when looked at with the eye fatigued with violet, the violet was darkened, the green extended towards the violet, and the blue crossed the line towards the violet. The blue in every way conducted itself like the yellow.

The line in the screen was then moved from the blue to the green, and the one eye fatigued with yellow and the other with blue. When the space between the yellow and blue was looked at, to the eye fatigued with yellow, the whole space had a bluish tinge; to the eye fatigued with blue, the whole space had a yellowish tinge; but there was

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no point in the two which appeared alike. The point of best green in both cases was *on* the line, though in one case it looked a yellowish green, and in the other a bluish green; and though it might be thought that some point on the blue side of the line in the yellowish green might have been found which would have corresponded to some point on the yellow side of the line in the bluish green, yet such was not the case. The yellowness and blueness entirely altered the appearance of the greens as seen by the different eyes. It would thus appear that the green is a compound sensation as well as the yellow, as it can be changed from green to bluish green and yellowish green. Yet it will be observed that, unlike the yellow, the position of the green in the spectrum cannot be changed. The three-nerve theory gives a reason for the change of sensation of the pure ray *i*, when the eye is fatigued; as also for the change of position of the yellow. To what, then, was the change in sensation of the green ray *k* due? To throw more light on the subject, the other primary colours were tested in the same way as the green. The line in the screen was placed in the red, and the one eye fatigued with purple, and the other with yellow. To the eye fatigued with purple, the red was darkened and tinged with yellow; and to the eye fatigued with yellow, the red was darkened and tinged with purple, but the position of the red remained the same. The line in the screen was then placed in the violet, and the one eye fatigued with blue and the other with purple. To the eye fatigued with blue, the violet was darkened and tinged with purple, and to the eye fatigued with purple, the violet was darkened and tinged with blue, but its position remained the same.

From these experiments it would appear that all our sensations of colour, even from the pure rays of the primary colours in the spectrum, are compound. Referring to these last experiments, we will take the case of the red looked at with the eye fatigued with yellow. The yellow would fatigue the red and green nerves, so that when red light falls on the eye it is incapable of exciting the fatigued green nerve; but the violet nerve being unfatigued, is excited, and the proportion which the sensation of the violet nerve bears

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to the sensation of the red nerve is increased on account of the diminished sensibility of the fatigued red nerve, the effect of which is, that the red sensation is mixed with the violet; the red, therefore, will appear tinged with purple. Again, when the eye was fatigued with blue, and green looked at, the green and violet nerves being fatigued, they are but little affected by the green light, while the sensation from the unfatigued red nerve bears too great a proportion to the others; the green, therefore, looks yellowish. In the same way, when the eye was fatigued with yellow, the green and red nerves being fatigued, the sensation of the violet nerve is in too great proportion, and the sensation is bluish green. In the same way, all the other changes which took place in the primary colours may be explained.

If this explanation be correct, then the sensation produced when, say a pure red ray falls on the eye, is not red, but a mixture of red and the other sensations. It is, so to speak, only a tint of red; the red is mixed with more or less white. If this be the case, then we ought to be able to purify the sensation, produced by even the red rays of the prismatic spectrum. If these red rays excite the red nerves, and also the other nerves, then if we remove the sensations of these other nerves, which we can greatly do by fatiguing them, the sensation produced by the red rays of the spectrum ought to be changed; it ought to be made purer, that is, the red part of the spectrum ought to appear redder. The experiment was tried. The one eye was fatigued by looking through blue glass at a gas flame for some time; this fatigued the green and violet nerves, and when the red part of the spectrum was looked at with the eye so fatigued, it looked much more brilliant than it did to the other eye. To the unfatigued eye, after looking at it with the fatigued eye, the red looked poor, as if mixed with white. So much improved was it, when looked at with the fatigued eye, that I may say, I had never seen red till that moment. The other primary colours were also tested in the same way, and found to be much purified.

Summing up these experiments, it was found that, as nearly as could be judged, the sensation produced by the

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pure rays of the primary colours was almost entirely the sensation of one nerve, mixed with a small amount of the sensations of the other two nerves. That the sensation produced by the red rays, for instance, was almost entirely red, mixed with a small amount of the green and violet sensations; whereas, the sensation produced by the *pure* rays of the secondary colours was found to be composed of the sensations of two of the nerves in equal proportions, mixed with a small amount of the sensation of the third nerve. The sensation produced by the *pure* yellow rays, for instance, was found to be composed of the sensations of red and green, in about equal proportions, mixed with a small amount of violet.

Impure Sensations—Its Cause.—It would appear, then, from the experiments described, that when a ray of any colour of light falls on the eye, all three sensations are excited at once. It does not matter how pure the ray may be, the sensation is compound. It has been shown for instance, that when the pure red rays of the spectrum fall on the eye, the sensation of green and violet are produced, as well as the sensation of red. The question then arises, How are these sensations of green and violet produced by rays of the red end of the spectrum? Are the green and violet nerves sensitive to these rays? Sir John Herschell thought that there are three species of light, and that "each of them has a spectrum of its own, over the whole length of which it is distributed according to its own peculiar law of intensity, and from whose superposition on the same ground, result the prismatic spectrum," so that every part of the spectrum would contain a proportion of each of the three kinds of light. "In this view of the subject" he says—"the prismatic colours, with the exception of the extreme red, are all more or less mixed tints." It being now generally admitted that there is only one kind of light, how, then, are we to account for the light of any one part of the spectrum producing all three sensations? Refering to diagram No. 4, how is it that the rays of the red end of the spectrum excite the green and violet nerves? Are all three nerves sensitive to rays of all the different parts of the spectrum? The only

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difference being that the different nerves are most sensitive to different parts of the spectrum. It will be extremely difficult to answer this question exactly. But I shall now attempt to show that the nerves are not so sensitive to all different parts of the spectrum, as would at first appear and that part of the sensation is due not to the direct action of the light on the nerves, but to some indirect action of the one nerve on the other. That, for instance, when red rays fall on the eye, the green and violet sensations which are produced are not the result of the direct action of the light on the eye, at least the greater part of the sensation is not, but that the green and violet sensations are induced by some action of the excited red nerve. It might easily be imagined, that if there are three separate sets of nerves in the eye, and these passing alongside each other from the eye, that when one nerve is excited it would act on the others, somewhat in the same way as when conductors of electricity are placed near each other and a current sent through one of them, it induces currents in the others, and if a galvanometer was placed at the end of each wire, the galvanometer at the end of the wire through which the current was sent, would be affected, and the galvanometers at the end of the other wires would also be affected. I do not say that this represents correctly what takes place; as there are marked differences in the two actions, but merely mention it as an aid to the imagination.

One reason for supposing that the three nerves are not sensitive to rays of all parts of the spectrum is, that whilst their sensibility to rays on each side of their maximum falls quickly, yet when it falls to a certain point it keeps nearly constant throughout the rest of the spectrum; and further, if the three nerves are sensitive to all the rays of the spectrum, we would expect that the red nerve, for instance, would be sensitive to rays for an equal distance on each side of its maximum, whereas, we fixed that it falls quickly, on each side of the maximum, and is extended or drawn out as it were only in the direction of the other colours, while it falls quickly to zero on the other side. The same with the violet, while it extends from its maximum through all the other

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colours and stops with them, it only extends for a short distance in the other direction. This extension of the sensitiveness only in the direction of the other sensations would seem to indicate that this extension was in some way closely connected with the other sensations. Viewing the subject in this way, there seemed a high probability of these compound sensations being due to some action of the nerves on each other, and not to the direct action of the light, I therefore endeavoured to test the subject by experiment.

It is generally known that when we look at a coloured object steadily for some time, and then direct the eye to a white surface, that we see an ocular spectrum of the same shape as the object, and of a colour complimentary to the colour of the object. The explanation of this being, that when we look steadily at the object, the nerves of the retina, at the point where the image falls on it, become fatigued to the light of the colour of object, whilst they remain sensitive to light of the other colours. So that when the eye is directed to the white surface it is not so sensitive to light of the colour with which it was fatigued. The white surface, therefore, seems deficient of that colour, or, in other words, is tinged with the complimentary of the colour of the object. Or, referring to diagram No 4:—Suppose the object to be coloured red; after looking at it for some time, the red nerve becomes fatigued, so that when the eye is directed to the white surface, the sensations from the unfatigued green and violet nerves predominate over the sensation from the fatigued red nerve, the resultant sensation being blueish. In this experiment the blue sensation is evidently the direct result of the blue rays of the white surface. But if the compound sensation given by the pure rays of the primary colours is produced by the action of an affected nerve on the others, then the ocular spectrum ought to appear, even though no light enters the eye, because the fatigued red nerve continues to be affected for some time after the light which fatigued it has been removed, it will therefore continue to affect the other nerves, and while the red sensation is fatigued, the green and violet sensations are unfatigued, and therefore the sensation of blue ought to be produced, even though no

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light is falling on the eye. When this experiment is tried, it is found that, after looking at a coloured object for some time, and then closing the eyes, and otherwise excluding the light, the ocular spectrum makes its appearance. We have here, then, a case in which an affected nerve acts on the other nerves and produces the sensation of colour, when no light is falling on the eye. But still there are some points in these experiments which require explanation before we can accept them in support of this point. For instance, after looking at the coloured object for some time, and the eye is either closed or directed to a white surface, the ocular spectrum does not appear at once, but so gradually that you cannot tell when it begins to appear. Now if the explanation given is correct, why does it not appear at once, as we might expect? I shall first consider the case in which the eye is directed to a white surface after looking at the coloured object. In performing this experiment, it is found that it is not till the eyes come to be fixed on some point, that the spectrum makes its appearance, or, as Sir Isaac Newton expresses it, when describing a different experiment, and one which nearly lost him his sight, that they appear when "the fancy is intended on them;" and I find that they may never appear at all, if the eye is kept wandering over the white surface; and after they appear, if the eye is directed to another spot they vanish. They also vanish after winking; in fact, anything which takes the *attention* from the spot spoils the effect. I therefore thought if the attention was always directed to the same spot, both when fatiguing the eye and when looking at the white surface, that the spectrum would appear at once; because in first looking at the coloured object and then directing the eye to the white surface, the attention is suspended during the time the change is being made, and it is some time before the attention is again concentrated on the spot. I therefore placed a small piece of coloured paper on a white surface, making a small mark in the centre of the coloured paper and a small mark on the white surface, the coloured paper was so placed that the one mark was over the other; the mark on the coloured paper was looked at steadily for some time, the coloured paper was then quickly

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removed. The mark on the white surface, taking the place of the mark on the coloured paper, enabled the attention to be kept on the same spot. In performing this experiment, not only was it found that the spectrum made its appearance the moment the object was removed, but it appeared in greater brilliancy than I had ever seen it. The change was so quick, that the spectrum seemed to flash on the eye. It is more difficult to produce the spectrum instantaneously, with closed eyes, as the simple action of closing the eyelids takes off the attention; but instantaneous spectra can be produced by using a black surface, which is similar in its action to closing the eyes, in place of a white surface in the former experiment. If the light from the object is very bright, the spectrum on the dark surface does not appear at once, but owing to the "persistence of the image" the impression of the object in its own colour remains some time, but quickly fades from the time the object is removed. Supposing the object looked at to be red, a red spectrum is first seen, which quickly fades and changes into blue.

It would appear, then, that one sensation, after it has acted for some time, has the power to produce the other sensations after the light which produced the first sensation is removed. Or, referring to diagram No. 4, it would appear that one nerve, after it has been affected by the light, has the power of exciting the other nerves after the light which affected the first nerve has been removed. If, then, the fatigued nerve, after the light has ceased to act on it, has the power of exciting the other nerves, it does not seem at all improbable that it will also have the power to excite these other nerves while the light is falling on it. That it has this power would seem to be supported by the following experiment:—If we look steadily at one colour, say red, the nerves gradually become fatigued, and the colour looses its brilliancy, and at the same time it changes to a lighter tint. This may be easily seen by looking with one eye at the coloured object and closing the other. After looking for some time, the eye is closed, and the unfatigued eye opened. The appearances which it now presents to the two eyes are very different, considering the sensation of the un-

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fatigued eye as the standard—to the fatigued eye it looks as if a white veil had been drawn over it. The green and violet sensations in the fatigued eye are in much larger proportion to the red than in the unfatigued eye, hence the white appearance. Referring again to diagram No. 4. The red light has first excited the red nerve; this, as it became fatigued would seem to have excited the green and violet nerves, and the longer the light has acted on the red nerve, and the more fatigued it becomes, the greater is its power to excite the other sensations; these compounding their sensations with the sensation of the red nerve, make the red light look as if it was mixed with white. The first sensation produced might be called the *direct* sensation, the other the *induced* sensation. All our sensations being compounds of these two. Again, all very bright, lights appear white. For instance the sun, when looked at through coloured glasses, appears always nearly the same colour. Does not this look as if when one sensation is strongly excited it in some way excites the others, the induced excitement being nearly equal to the direct excitement of the light, when the light is bright.

From all these considerations, though the proof may not amount to a certainty, yet there seems a high probability that the compound sensations produced by the pure rays of the primary colours are greatly, if not entirely, due to some action of the eye on itself, and not to the direct action of the light. According to this three-nerve theory, when a pure ray of one of the primary colours falls on the eye, it produces a *simple* direct sensation, which by some action of the eye excites the other sensations, and these induced sensations become compound with the direct sensation; so that we never have a simple sensation of colour unless certain precautions are taken, and even then it is not absolutely simple, only less mixed; and when a pure ray of any of the secondary colours falls on the eye, it produces a *compound* direct sensation, which induces the other sensation, these becoming compounded give us the resultant sensation, which we recognise as the colour of the light. This action of the one nerve on the other might in one sense be considered a defect in the eye, while in another sense it is an advantage, as it gives

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rise to a greater variety of sensations, and plays a most important part in what is called the contrast of colours.

Contrast of Colour—Chevreul showed that side by side with the visual perception of any colour there arises, without the exercise of long gazing, the impression of its complimentary. This he called simultaneous contrast of colour, to distinguish it from the contrast resulting from gazing first at one colour then at another, which he called successive contrast. I shall endeavour to show that this simultaneous contrast is greatly due to successive contrast, that it is but a *quick* successive contrast. Suppose we have a piece of paper, one-half of which is coloured violet, the other half yellow, if we look at the paper at the line where the two colours meet, the violet and the yellow seem brighter for a small space on each side of the line than they do at any other part. That this brightness on each side of the line is due to successive contrast may be proved by fixing the eye steadily on a point in the line, when the brightness along the line disappears, and the colours seem uniform up to the line, and it is only when the eye is allowed to wander from one side of the line to the other that the colours on each side appear changed. In performing this experiment, it will be noticed that the effect of the contrast is greater when the line between the colours is vertical than when it is horizontal. This is probably caused by the eye, when looking at objects, moving more in a horizontal than vertical direction, so that when looking at a coloured paper with the division line vertical, the eye passes from one colour to the other across the division line, whereas, when the division line is horizontal the eye travels back and forward along the line, so that the same colours continue to fall on the same parts of the retina. This restlessness of the eye is in all probability the cause of many optical phenomena, amongst others the following:—When we look at a coloured space, there is developed round the edge of the space a breadth of complimentary colour, this is due to the eye being directed to different parts of the edge of the space, so causing the image to fall on different parts of the retina, which gives rise to the complimentary colours in the same way as when glancing from side to side of the division line between the

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yellow and violet. There is also another class of phenomena which may also be accounted for in the same way, Rumford showed that when a shadow is produced within coloured light, the colour of the shadow is complimentary to that of the light. I performed this experiment in the way described by Sir D. Brewster. Having lighted two candles, and placed before one of them a coloured glass,—in this case red,—the other candle was removed to such a distance that the two shadows of a body formed on a white surface were equally dark —the one shadow was red, the other bluish. But I find that at first the blue shadow had no perceptable colour; and it was only after the eye had wandered over the red surface to compare the one shadow with the other that the blue colour was produced by successive contrast. The oftener the eye moved from the one shadow to the other the brighter was the blue shadow. What is generally called Irradiation would also seem to be in part due to this restlessness of the eye. When we look, say at a small round spot, it looks larger than it really is, the wandering of the eye causing its image to be spread over a larger space of the retina than if the eye was kept steady. Part of this larger appearance is also due to the very small space of the retina over which we have accurate vision; on all sides of this space the definition is indistinct and confused—as if the image was not properly focused, some of the rays seem to fall beyond some within the true boundary line; but if the eye be directed to a point on the edge of the spot and kept steady on it, the spot at that point does not appear larger than it really is, unless when the light is very brilliant.

The best manner of studying the change which takes place when two colours are contrasted is to place strips of the two colours close to each other, and at a point about one eighth of an inch on each side of the division line between the two colours make two small marks, look first at the one mark steadily for a short time, then at the other, when a band of colour about a quarter of an inch broad, as changed by contrast, will be seen running parallel with the division line, you have thus presented to you on the same surface, and alongside each other, the sensation of the colour itself, and the sensa-

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tion of the colour as changed by contrast. Supposing the colours looked at were blue and violet, if you first look at the mark near the edge of the violet, then at the mark in the blue, you will see a greenish-blue band on the blue running parellel with the division line between the colours. The object of looking steadily at a point on each side of the line is that we get a well defined band of colour as changed by contrast, which can easily be compared with the unchanged colour. If we have not fixed points to look at, the colour, and the colour as changed by contrast, seem gradually to fade into each other

I shall now consider the bearing of the previous experiments on the causes of this change when colours are contrasted. When colours are contrasted, there are four causes all acting to produce the change. There is 1st, the purely mental cause; as when a large and a small body are compared, the one looks larger, and the other smaller, than it really is; 2d, the reduced sensibility of the fatigued nerves to the direct action of the light; 3d, the insensibility of the fatigued nerves to the induced sensation; and 4th, the induced sensation of the unfatigued nerves. The first of these causes need not be considered here. The second cause comes into operation when two colours are looked at which have a sensation or colour in common, as when yellow and red are contrasted. The red fatigues the red nerve; so that when yellow is looked at the green sensation predominates over the red and makes the yellow look greenish, and when red is afterwards looked at it seems duller, This second cause, also tends to make impure colours seem purer. When we look at violet and then at yellow, the violet fatigues the violet nerve, so that when the eye is directed to the yellow, the small amount of violet rays in the yellow have not the power to affect the fatigued violet nerve; the yellow, therefore, look yellower, and if the eye is afterwards directed to the violet, the red and green rays in the impure violet have no power to affect the red and the green nerves, on account of their having been fatigued with the yellow. Third cause. When any colour is looked at, all three sensations are produced; and we showed that part of that sensation was due to the direct

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effect of the light on the nerves, and part is induced by the excited nerves; but if the nerve is fatigued, the induced sensation is not produced in it; so that suppose we contrast yellow and violet,—if we first look at the violet, the violet sensation is produced,—this induces the green and the red sensations which combine with the violet; but if, before looking at the violet, we look at the yellow, the red and the green nerves will be fatigued; so that when we look at violet, the red and green sensations are not induced, thus causing the sensation to be purer. If we afterwards look at the yellow, the excited green and red nerves will be unable to induce sensation in the fatigued violet nerve, the sensation will therefore be purer. Fourth cause. When any sensation is directly produced it induces all the other sensations. This induced sensation, we showed, continued after the light which produced the first sensation is removed; so that, in contrasting yellow and violet, if we first look at the violet, the red and green sensations are induced, and these continuing to act after the eye is directed towards the yellow, the induced red and green sensations are added to the direct red and green sensations. Again, the yellow will directly excite the red and green nerves, and induce the violet sensation, so that when the violet is looked at, the sensation is a compound of the direct added to the induced violet sensation. This induced sensation will only act for a very short time, and will cease whenever the light begins to fatigue the nerves.

When we contrast complimentary colours, the four causes all act in the same direction, tending to purify and brighten the colour—the first by the mental effect; the second by making the colours appear purer than they really are; the third by preventing the eye from adding the induced sensation of the light falling on it to the direct sensation of the light,—the induced and direct sensations being different, would tend to make the sensation more compound; and fourth, by the eye adding the induced sensation of the light which previously acted on it to the direct sensation of the light falling on it. These sensations being the same, tend to brighten the colours. When colours not complimentary are contrasted they are changed in colour towards the

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sensation least excited. Supposing red and green are contrasted: if we first look at the green and then at the red, no sensation will be induced in the fatigued green nerves when red light falls on the eye, but the violet nerve being unfatigued, sensation will be induced in it; the red therefore appears tinged with purple. If we afterwards look at the green, no sensation will be induced in the fatigued red nerve, but the unfatigued violet nerve will be excited; the green, therefore, looks tinged with blue. Again, if we contrast yellow with blue, the yellow looks reddish. The blue fatiguing the green and violet nerves, the green in the yellow does not affect the fatigued green nerve so much as the red does the unfatigued red nerve,—the sensation is therefore reddish. This redness is also intensified by the induced red sensation produced by the blue rays—which previously fell on the eye—being adduced to the direct red sensation. Again, when red is contrasted with yellow, the red fatigues the red nerve; so that the sensation produced by the green in the yellow is greater than the sensation of the red,—the yellow therefore looks greenish. Again, the red induced the green sensation, which continues after the eye is directed to the yellow. This, also, tends to make the yellow green when first looked at. And further, the red having induced the violet sensation, this will also be added to the other sensations, and tends to make the yellow look whiter. When black and any colours are contrasted the black seems tinged with the complimentary of the colour with which it is contrasted. If violet and black are contrasted, the black seems tinged with yellow. The violet sensation induces the red and green sensations which continue to act after the violet light has ceased to fall on the eye, or when the eye is directed to a black surface. The black, therefore, appears tinged with yellow. Hence it is that shadows of objects, or the shade side of objects, appear tinted with the complimentary colour of the object. This explains the reason why, in painting, the shadows are tinted with a colour complimentary to the high lights. In painting a portrait for instance, the shadows in the face are painted of a bluish colour, which is complimentary to the

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flesh tints. The reason why the shadows in painting are tinted with a colour complimentary to the high-lights, when the shadows are not so coloured in nature,—only appear so to the eyes,—would appear to be, that the light from objects in nature being much more brilliant than from paintings, and produce those effects in the eye which the weaker light of the picture cannot produce. The weak light from the picture not being able to cause the eye to produce the complimentary tints, these complimentary tints must be produced in the painting itself. The complimentary tints will have the effect of brightening the high lights and making the picture appear more brilliant.

It is astonishing how much of the beauty of nature is due to this painting by the eye; many of the most beautiful and softest tints in landscapes have their existence only in the eye. Who has not admired that beautiful ethereal blue tint which is sometimes seen on our mountains at sunset? and yet, strange to say, in many cases no rays corresponding to that beautiful tint exist in the landscape,—the blue tint has its origin in the eye of the beholder. The golden sunset, with its orange-coloured clouds, is the cause of the apparent colour on the hills. This may be proved by fixing a screen in such a position as to shut out the sky, when the beautiful colours will fade from the hills, and the landscape become cold, gray, and uninteresting. The blue-violet colour of the hills would appear to be produced in the eye in the following manner:—When the eye is directed to the brilliant yellow and orange light of the sky, the red and green nerves are fatigued, but the red nerve most; so that when the eye is afterwards directed to the hills, the dull light reflected from the hills, and from the white vapour which hangs around them, produces no effect on the fatigued red nerve, and but little on the less fatigued green nerve, but is capable of affecting the unfatigued violet nerve, causing the hills to appear bluish violet; and further, the brilliant orange and yellow light of the sky will have produced a strong induced blue-violet sensation. This will also be added to the direct sensation, making the colour of the hills appear more brilliant. This soft ethereal colour often seen on the hills

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at sunset strongly reminds the observer of the soft and strangely unreal colours induced in the eye when the eyelids are closed after looking at a coloured object; both are partly due to the same cause, namely, the induced effects of light which previously fell on the eye.

Colour-Blindness.—I shall now refer briefly to the probable causes of colour-blindness suggested by the three-nerve theory, but which I regret I have been unable to test by experiment, on acccount of not being able to find any cases of true colour-blindness. The marked characteristic of most cases of colour-blindness, given by Sir D. Brewster and others, is the inability to distinguish between reds and greens. But in some cases they were unable to see red, it looked black, and in one or two cases they could distinguish no colour, only different brightness. This inability to distinguish colour might arise in four ways. The first is, that the sensations of two of the three nerves might be the same. That is, supposing our sensation of the three colours to be represented on a plane by the three angles of a triangle, and the distance between the angles or the length of the sides to represent the difference between our sensations,—supposing red to be placed at one angle, and green and violet at the other angles, then for most eyes the triangle would not be an equilateral triangle, but the side between the green and the violet would be shorter than the other two, because the sensation of green is more similar to the sensation of violet than green is to red or red is to violet. For those who mistake red for green—the triangle representing their senations would have the side between the green and red much shorter than the other two sides, as their green and red sensations are almost alike. There is no reason why this might not be so, as in all probability the sensations of red, green and violet, are different in different individuals. The second probable cause is, that the nerves, instead of being equally distributed over the spectrum, as shown in diagram No. 4, might be so constructed that the red nerves might be sensitive to all the rays to which the green nerves are sensitive, and the green nerves sensitive to all the rays to which the red nerves are sensitive. Now, suppose any

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rays of the spectrum from the red to the green, to fall on two sets of nerves so related, both sets of nerves would be excited, and the sensation produced would be what we call yellow, so that the nerves might be actually conveying the sensations of red and green, and yet the person might never know the sensations of red or green, because neither of these sensations had ever been excited separately. The third possible cause is the want of one of the sets of nerves. This would seem to be the case in those who mistake red for black, orange for green, and violet for purple. The red nerves being absent, they are only conscious of the excitement of the green set of nerves when looking at orange, and for the same reason they cannot distinguish between violet and purple. The red sensation being absent, the purple can only affect the violet nerves. Fourth possible cause. The induced excitement might be equal to the direct excitement. In this case, if the three nerves were all equally sensitive, to the induced sensation, only one kind of sensation would be produced, all objects would only differ in brightness. In most cases on record of colour-blindness, the red and green are the colours which oftenest cannot be distinguished from each other. But it is to be feared that colour-blindness is not confined to this end of the spectrum, but is quite as common with colours at the violet end. Many people are always confounding blues, violets, and purples. Though in most cases I have examined this result more from want of observation and knowledge than from colour-blindness; because, when shown these colours side by side, they could easily distinguish one from the other. So much confusion is there regarding colours at this end of the spectrum, that I have been unable to get a violet pigment. All the so-called violet dyes and pigments contain a large amount of red in them; some of them are more properly purples than violets. A fair violet may be produced by mixing one of these violet dyes with a blue pigment which does not act chemically on it. The blue stops back the red rays which come through the purple, and both pigments pass the violet rays.

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Notice regarding the Construction of Sewerage and Sanitary Apparatus. By JOHN PATERSON, C.E.*

A great alarm has been created throughout the kingdom in consequence of the late severe illness of the Prince of Wales and others, from the effect, as alleged, of their having inhaled poison from the foul odours of the sewers of a shooting lodge, which was defective in its sanitary arrangements; and therefore important questions continue to be discussed as to how it is possible to prevent the recurrence of such dangerous results, and the most approvable means to be adopted for accomplishing this object.

These questions, as might be expected, have been variously treated by the several persons who have lately taken occasion to state their views in newspapers and other public journals. One class has represented the solution of such questions to be so extremely simple, that the whole principles connected with construction of sewerage, and the requisite remedies for defects, have been quite familiar to them from the first; while others do not seem to regard the professed knowledge of such principles as being of much advantage, unless founded on and carried out under the provisions of the most secure legislative superintendence; and it is somewhat to be regretted that the statements generally made have had more of alarming tendency than being in any way useful to point out the means to be employed for a safer mode of construction or the more effective cleansing of sewers.

The general impression of the public mind at present appears to be, that sewerage at best is a very crude and doubtful kind of operation; and although it be admitted that some streets and districts are in healthy sanitary condition, there being others less so, and some exceptional houses found to be unsafe, it is therefore assumed that there cannot be any such known general law for carrying out sanitary works as to warrant the confidence of the public.

Where due attention, however, has been given to modern

* Read before the Society 12th February 1872.

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sewerage operations, the main sewers in populous streets of large towns are carefully constructed of ellipse form, built of composition bricks in cement, having provision made for branch and house drainage; and in smaller streets, the main sewers consist of spigot and faucit salt-glazed pipes, all jointed with cement, and all parts of the work made thoroughly water-tight.

The main sewers are made sufficiently large to carry off the amount of water supply, and where storm water is taken in, the maximum rain-fall of the area draining into the sewer requires to be added to its capacity, and in all cases the main sewers are placed at such depths under the levels of the lowest floors, as to afford a gradient of not less than 1 in 48 on the house drains at the upper end of the main drain.

Where the gradients of main sewers exceed 1 in 350, and of small size and great length, there should be flushing tanks containing about 120 cubic feet each, at not more than from 350 to 450 feet apart, according to the size of the sewers, and number of junctions, so that they may be scoured out at least once a week.

House drains are formed of spigot and faucit glazed pipes, of from 6 to nine inches interior diameter, according to the size of houses, and if all laid correctly as to gradients, and not less than from 8 to 10 feet radius turnings, and the joints properly secured with best quality of Roman or Portland cement, there should not be any such accumulation of sewage deposit possible as to become putrid, or cause nuisance from decomposition, and this should especially hold good in the larger and best class of houses, which are fitted up with baths and sinks, and best quality of water-closets, fixed washing tubs, and all other improved sanitary apparatus.

It was stated very recently, in one of the Edinburgh papers, that the main cause of defects in the construction of house drains is attributable to the want of legislative powers to enforce effective superintendence; but this statement must have been made in ignorance of all connected with such public works, as will be seen by referring to the follow-

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ing clause of the Public Health (Scotland) Act, viz.:—"That if any house within the burgh be at any time not drained by a sufficient drain or pipe, the Commissioners shall construct or lay from such house a covered drain or pipe, of such materials, of such size, and with such fall as the Commissioners may think necessary for the drainage of such house or building, its areas, water-closets, privies, &c.; and the expense thereof shall be recoverable from the owner of such house," &c.

It will be observed from this and similar clauses in the other public sanitary Acts, that the Commissioners have ample powers for the construction of house drains; but it is well known that hitherto Police Commissioners have found it to be a delicate matter to insist on such stipulations, under the impression that as proprietors have most risk, and should feel the greatest responsibility regarding their property being substantially and satisfactorily drained, it has been deemed advisable not to urge new measures too much; and with intelligent proprietors, who really adopt the best means possible for having the work properly executed, the matter might be safely enough left in their hands.

It must be admitted, however, that the class of proprietors referred to are not in all cases the most numerous, and many instances will be found where proprietors, most anxious to have their drains satisfactorily executed, have been subjected to great nuisance and loss, from gross carelessness on the part of those to whom the work was intrusted.

As evidence of this, I may refer to the case of an eminent engineer, who, on enlarging his mansion-house, also laid down larger house drains, and within about three years afterwards it was found that part of the garden ground had become so saturated with sewage as to compel the inhabitants to leave the house, and on lifting and relaying the drains they ascertained that the nuisance was caused by a void of nearly a yard in length of the pipe having been entirely left out. Another case which came under my observation, was that of the house drainage of a learned doctor, at one time president of this Society, and where the nuisance

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was so intolerable as to cause disease, and it had been determined on to leave the house, when, fortunately, it was discovered that a large area of the garden ground was fully saturated with sewage, issuing from a wide gap where the drain track had been filled in with loose stones instead of sewer pipes. Also the case of a new mansion, where the bottom of the lead pipe of the ground-floor water-closet was merely set in loosely into the drain pipe; and the excuse offered was, that in strict terms the making of that joint was not in the specifications.

Let us hope that such cases as these are rare exceptions; but however this may be, the perpetration of such acts of gross carelessness can only be accounted for as arising from entire ignorance of what is required in the construction of sewerage.

At one time observing house drainage being carried out in a very rough and slovenly manner, I took occasion to ask the builder whether he considered it necessary to be particular with such work, to which he gave the prompt reply, "Certainly not, it is all covered up." Now, I believe that so long as sewerage is allowed to be carried out by men of this grade, we must expect to fall in with occasional cases of the kind referred to, as no superintendence can be effective in improving their covering up notions of executing works.

When sewerage, however, is executed in a fair and legitimate manner, viz., the work systematically carried out, and the sanitary apparatus of good quality, as in the larger class of houses, there should not with ordinary care be any risk of nuisance; and from the extensive examinations I have lately made, I would venture to say there is no risk of danger from foul odours, but in the smaller class of houses more care is required, in consequence of the sanitary apparatus being of inferior quality, and less water used, but even with all these comparative disadvantages, I have often found small class houses with good housewives equal to the best of the larger class.

It may be confidently asserted that with the best sanitary apparatus cleanliness does not become self-acting, and in

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the case of water-closets, however perfect the water trap bends and service to the basin may be, it is possible that by the careless use of the closet, part of the back of the basin, and what is termed the trunk or conical head of the lead pipe, may become clotted with filth, and pollute the whole house, especially where the effluvia can pass under floors and through other open spaces. Similar nuisance may also occur where grease and pieces of animal matter are allowed to decompose in the bend traps or cesspools of sinks.

The water stops, or what are termed cesspool bends of sanitary apparatus are found, if properly constructed, to be quite effective in preventing foul odours from passing up through the pipes, but the water by long standing becomes saturated, and then the gases pass through it; it is therefore requisite that in houses shut up for some time, care should be taken to make a safe renewal and clearing out of all the foul traps before the house is occupied.

It is also most essential in all cases to have the chambers of water-closets well-ventilated, so that the circulation of air may pass through them without requiring to open the doors, and that the ventilating mediums have full control in driving off the foul odours from under the seat, which accumulates by frequent use of the closet, and is often mistaken for leakage from the drains.

The ventilation of sewers has been much discussed lately, and from what has been stated, the public generally are of opinion that there is no outlet for ventilation at present,—that every street eye, &c., being sealed up, the foul odours are necessarily forced into dwelling-houses, and must create all kinds of fevers and every other malignant type of disease.

A gentleman of extensive scientific knowledge lately stated to me, that he had been told his large mansion was in such a condition from want of outlet for the sewer gases to escape, that it might at any time become a hot-bed of disease, and he was most anxious that something should immediately be done to prevent such a dreadful state of matters.

Instead of proposing to make such extensive alterations as he had been led to expect as necessary, he seemed very much surprised by the explanation that his numerous rain-

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water conducting pipes were in direct connection with, and provided free outlet from the house drains, forming upcast and downcast tubes according to their respective positions in being exposed to heat or cold, and that the heads of these pipes were also sufficiently high to be safe above all the windows.

What was found to be the case in this mansion is only the ordinary construction of other dwelling-houses, and with very few exceptions the whole of the conducting rain-water pipes of towns, form outlets from the drains; many of them, I believe, may be somewhat dangerously so, from being too close to upper windows, and it will be well when a safer and more effective system of ventilation can be carried out; but by the present state of matters there is no real cause for the public alarm that has been raised, as to gases being shut up into the sewers.

When proper structural works for ventilation are carried out in connection with sewerage, and which, I presume, will require to be done under the provisions of statutory powers, so that shafts or large tubes, &c., may be erected in the most suitable places, I expect it will then be found, as experiments already prove, that instead of trying to force out, or, what is termed by many, draw off all gases at the upper end of the sewerage, whatever its length may be, it will be found necessary to commence at the lower end, and proceed upwards to erect shafts in the positions to command the greatest number of the junctions of tributary sewers.

I am fully persuaded that the system invented, and so successfully tried about ten years ago by a London chemist, viz., that of deodorising the foul odours by allowing them to pass through boxes of charcoal in openings over the sewers, would be the best and safest mode of ventilation that could be adopted, although it would be open to the often urged objection to all other methods required for cleaning, that of its not being self-acting. The boxes of charcoal, however large and dry kept, would require to be renewed at least once a week, but the same staff of men in charge of the flushing could also attend to the ventilation.

There is one difficulty connected with, and running

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through the numerous letters which have appeared in public papers regarding ventilation, and that is, that almost all representations made on the subject are to the effect that gas in sewers is a new discovery, and the removal of it by the kinds of ventilation proposed would be sufficient to supersede the necessity of careful construction, or flushing, or washing, or other sure and safe means of cleansing.

Now this, to say the least of it, is rather embarrassing, and has caused many who have given some attention to the subject, to inquire whether there would not be the greater absorption and less creating or generating of effluvia of gases, and greater safety ensured, by thorough cleansing, than by leaving the whole matter to uncertain ventilation.

Whatever the representations may be, I do not think that those who are advocating ventilation can believe it is sufficient to overtake all that is necessary for the cleansing and purifying of sewers, but, as in all cases of alarm, it is generally found that many are ready to give attention, and suggest such remedies as they may consider most favourable, it would be well, however, that instead of attacking the main sewers, the remedy for foul gases were applied to house drains, which are the sources of filth. And from all that is at present known, it appears most desirable that active means should be adopted to prevent the dangers arising from carelessness, and want of proper arrangements connected with the construction of sanitary works.

Notice of Condensing Intermittent, and Revolving Lights. By THOMAS STEVENSON, F.R.S.E., M.I.C.E., Civil Engineer.*

The accompanying drawing represents an azimuthal condensing intermittent light, by which the intervals of light and darkness can be allocated within limits practicable in any proportion, and the strength be thus largely increased of the sectors lighted, while the intensity is made equal throughout each of such sectors.

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* Read before the Society, on 8th April 1872.

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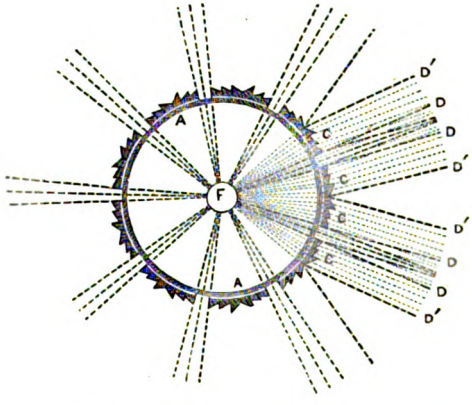
The diagram represents a medial cross section of the apparatus.

The inner zone, marked AA, represents Fresnel's fixed light apparatus, which parallelises rays in the vertical plane only. CC are prisms, straight vertically, which spread (as shown by D'D'), over the horizontal sectors DD, which have to be lighted, the rays coming from the fixed apparatus. The light from the fixed apparatus A, spreading over the sector DD, is thus to a *distant* observer strengthened by the rays from the revolving prisms CC. The same distribution of the light which is shown on the right side of the diagram, is, of course, repeated over the whole circle.

If the straight prisms be made to revolve round the fixed



light apparatus, there will be produced intervals of light of uniform intensity while the straight prisms are directed to the eye of the mariner, and dark intervals when they are directed away from his eye.

Although it is theoretically possible, by breaking up the cylindric zones of the fixed light apparatus into polygons and altering their forms, to effect by single agents the same object as has been described, yet the difficulty of execution would probably be insurmountable. The differential reflector, as described in "Lighthouse Illumination,"* might,

* "Lighthouse Illumination." 2d Edition. By T. Stevenson, F.R.S.E., Edinburgh, 1871, pp. 15, 99, 110.

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however, be made available for such a purpose, but in this case there would need to be a revolving frame with one or more reflectors, each having a light of its own.*

Ordinary Lens giving Sector of Uniform Intensity.—By means of the ordinary annular lens, used in conjunction with straight prisms placed on either side of its vertical axis, the small arc which is unequally illuminated by the lens in its present state, may be made of uniform intensity in azimuth throughout the whole arc. Such an arrangement may by itself be useful when dealing with certain cases of illumination.

Revolving Condensing Lights.—An arrangement similar to that for intermittent lights is, when used in connection with differential lenses, obviously equally applicable to a revolving light, in which a larger illuminated sector is required than that afforded by an ordinary holophotal apparatus. In such a case, the rays instead of being spread equally over the whole sector as in the intermittent light, would be made to decrease in intensity towards each margin of the sector, so as to produce an illuminated space of any given extent in azimuth, preceded, and succeeded by a gradual waxing and waning of strength.

Composite Optical Panes of Coloured Glass for Lighthouse Lanterns. By THOMAS STEVENSON, F.R.S.E., M.I.C.E., Civil Engineer.†

Every improvement on lighthouse apparatus may be resolved simply into a method of preventing loss of light. Successive savings have again and again been attained, sometimes by substituting a material which absorbs less

* Since the above was written, I have got a mould for the differential reflector, executed in plaster by means of an ingenious *trainer*, suggested by my friend Professor Tait. I have preferred elliptic horizontal sections, the vertical being, of course, parabolic. I think it not improbable that a differential holophote may be constructed of *totally reflecting prisms*, bent when hot over an iron mould, so as to make their reflecting surfaces elliptic, while the other faces would, in order to avoid refraction, be spheric and normal to the direction of the rays.

† Read before the Society, on 8th April 1872.

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light, and is susceptible of greater accuracy of form, for another which absorbs more, and is less easily and accurately manufactured. Sometimes similar results have been achieved by altering the principle of the apparatus, so as to dispense with one of the optical agents formerly used.

The object of the present communication is to point out where there is a promise at least, of securing a farther economy of light.

When colours are used as a distinction, and where the back rays are not reversed and made to pass again through the flame, but are passed at once from the flame to the apparatus, and from the apparatus to the sea, the best method of colouring the light, is to tint with the proper colour the glass chimney above the flame. But most coloured lights require such a distribution of the rays as to render it necessary that some part, at least, of the light should be returned through the flame before it emerges finally seawards. In such a case, it must be obvious that if a coloured chimney be employed, the light will not be all of one shade, for the portion that passed *twice* through the coloured chimney will have attained a deeper shade than that which passed only once through one of its sides. So that if those rays which pass once through the chimney be sufficiently distinctive, which they ought to be, then it follows that there is a loss of light occasioned by the transmission of any of the rays a second time through the coloured chimney. In order to avoid this loss, a colourless chimney is used, and coloured shades are fixed either immediately in front of the apparatus itself, or else close to the panes of the lantern of the light-room, in which latter case, owing to their proximity to the lantern, causing a want of proper ventilation, condensation takes place in certain states of the weather involving a great loss of light.

It is of course well known, that wherever rays of light pass from one medium to another of different density, there will, unless at normal incidence, be refraction, and when the incidence is not normal to the surface, there will be a loss of light by superficial reflection. There will, therefore, excepting in the case mentioned, be a loss of

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light as often as the rays encounter different parts of the apparatus. If, however, as has long been practiced in the preparation of certain optical instruments, two pieces of glass be united together by means of a transparent cement, which has the same, or nearly the same index of refraction as the glass, a ray will pass through such a composite prism, without suffering any notable refraction at the inner surfaces; and on looking through such a combination of materials, the two inner surfaces of the plates of glass will be invisible, simply because the light passes from the first side of the glass into the cement, and from the cement into the second piece of glass without suffering any appreciable change in its direction, any more than it would, had it passed through a piece of solid homogeneous glass of the same thickness as the compound mass. Such a cement is the well-known Canada balsam, a natural production which has very nearly the same index of refraction as crown glass.

If the plates of coloured glass be cemented in the case I have supposed to the emergent or outer faces of lighthouse apparatus, the rays will pass from the glass of the apparatus through the Canada balsam into the coloured glass, practically speaking, without refraction, and therefore without loss of light by superficial reflection, and in this way the loss at two surfaces will be saved. For if the light be allowed in the ordinary way to pass through coloured shades placed outside of the apparatus, there will be a loss on the emergent or outer face of the apparatus, on the immergent or nearest face of the coloured shade, and lastly on the emergent or outermost face of the shade; whereas, by the proposed arrangement, the emergent or outermost face of the apparatus and the immergent face of the shade are virtually abolished by the Canada balsam, and the only appreciable loss will be in passing through the outer or emergent face of the coloured shade. So that the loss by superficial reflection is saved for two surfaces. The loss generally taken for polished surfaces is $\frac{1}{30}$th of the whole, so that $\frac{2}{30}$ths or $\frac{1}{15}$th of the incident light is saved. But this is not the whole saving; for the kind of glass which is employed for colouring never, and indeed cannot receive on both sides by the present mode of manufacture, a polished surface, so that

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the real loss due to irregular reflection, and to irregular scattering must be considerably more than $\frac{1}{15}$th. The only experiments on the loss of light through unpolished glass, with which I am acquainted, are those given by Count Rumford,* in his "Philosophical Papers," who found that the loss in passing through a "very thin clean pane of clear white or colourless window glass not ground," varied from ·1213 to ·1324; so that allowing for the loss by absorption in passing through this "very thin" pane, we shall certainly save more than $\frac{1}{15}$th of the whole incident light. In order, however, to take proper advantage of the proposed construction, it is necessary that the coloured side of the glass should be placed next to the outer face of the apparatus, so as to admit of the outer or uncoloured surface of the shade being polished—a process which can easily be accomplished after the plate of glass has been fixed to the prism by the Canada balsam. It may, perhaps, be thought that there will be an increase in the amount of polishing, because the outer surface of the coloured glass will require to be polished as well as the surfaces of the prisms. This, however, is not necessary; because, although the outer face of the apparatus be left unpolished, the Canada balsam, which cements the pane of thin coloured glass, will, by abolishing practically the surfaces, render the irregularities of no real consequence.

In some cases it will be more convenient to cement the coloured glass to the plate glass panes of the lantern. But this arrangement will not affect the gain of light, which will remain the same as in the former case just described.

Description of a Model and Apparatus by which Switches and Sidings are worked by the Man on the Engine or Train; Invented and Applied by JOHN SCOTT, *Manager of Garriongill Collieries, March* 1872. Read by D. LANDALE, M.E.†

The Garriongill pits, five in number, are situated on the steep bank of the Clyde, on the estate of Coltness, for the supply of the iron works there. They are situated far

* Philosophical Papers, by Count Rumford. London, 1802, vol. i. p. 299.

† Read before the Society, and working model exhibited, on 8th April 1872.

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under the level of the Caledonian and other railways connected to the ironworks, and access to them is obtained by a single inclined plane of about 1200 yards in length, worked by a stationary engine at the top, with a wire rope running on pulleys in the ordinary way. The first 300 yards is on a gradient of 1 in 22, increasing as it descends. The second 300 yards being about 1 in 12; then 400 yards of it average 1 in 8, and the last 200 yards as steep as 1 in 5. The empty waggons take down the rope at a speed of about ten miles an hour, and the engine draws up the loaded waggons in trains of a dozen of waggons or so.

There are six branches, or off-sets, with switches going off this incline at different places right and left to the pits. One man has charge of and rides up and down with the train.

All the points are kept constantly shut, either by springs or weights. The bankman on the train has the means of opening any or all of these points, while he sits on his waggon. Having selected the branch into which he is to take his waggons, he opens all the switches as he approaches them, and keeps his course until he reaches the one he is to enter.

The mechanism for opening these points is of the simplest character, as will be seen from examining the model, which is made to a scale. Although only one waggon is exhibited, there may be twelve or twenty, or whatever number is required.

There is a bell-crank lever, with a chain on its short end, passing over a pulley, and attached to the switch. The long arm of this lever is bent, so as to form a long flat incline rising in the opposite direction to the rails.

There is a moveable outrigger on the first waggon of the train, furnished with a roller on its end. This rigger is fixed on a pivot, and is easily turned inwards or outwards; and when out, it is held there by a catch. As the train advances, this roller bears on the inclined bent lever, opens the switch, which is then kept open by a spring catch,—shown on the model,—and remains open until the train has passed the crossing, when the same outrigger and roller strikes an upright lever and liberates the catch, and lets the

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switches shut by the weights arranged for that purpose. This upright lever is placed at such a distance and with such a length of chain or wire rope as give space for the trains to pass the switches (although in the model it is only placed to let one waggon pass for convenient inspection).

The whole thing works nicely. They have been at work for nearly two years, without the smallest accident or mishap of any kind. Their action is most certain, for if the banksman were inattentive, the train would merely enter the first siding, and no more could be done until he signalled to have them pulled out of the way or otherwise disposed of. Each set of levers, weights, and catches, costs about L.3. It dispenses with a man for opening and shutting the switches. It is admirably suited for working the mineral sidings and switches between an ironwork and the coal and ironstone pits, which are usually wrought with a small locomotive, having a driver, stoker, and a third switchman on the back end of the train, whose duty it is to jump up and down the whole day, opening and shutting switches, a duty attended with some little danger. This arrangment of Mr Scott's, applied to such roads and traffic, would save this man and a deal of time and risk. It has not been applied to locomotive trains as yet; but I have no doubt it will be, if brought into proper notice.

I was so struck with its simplicity and effectiveness, that I asked Mr Scott to prepare the model, which I undertook to bring before and explain to the Royal Scottish Society of Arts, which I have now done, in the hope it will be remitted to a committee of Fellows to report on its merits.

On a simple way of showing the Motion of Waves on the Surface of a Liquid. By Robert M. Ferguson, Ph.D., F.R.S.E. *

We are all familiar with the fact that when a stone is thrown into smooth water a series of concentric circles proceeds outwards from the point of disturbance. This seemingly trivial phenomenon assumes real importance

* Read before the Society, 11th March 1872.

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when we take our first lessons in sound, or the theory of light, for sound certainly, and light as far as analogy can prove anything, are also propagated by waves. The force at work in the propagation of waves on the surface of a liquid, is gravity, whereas it is the elasticity of air and ether which are concerned in the propagation of sound and light. Water waves, at least so far as we see them, are circular, and in one plane. Those of sound and light, on the other hand, are globular, and in all directions. Notwithstanding these and other differences, there is still such a resemblance subsisting, that whenever waves of any kind are to be explained or graphically represented we have invariably to recur to the surface waves. The student or teacher of the ordinary phenomena of the propagation, reflection, or interference of waves could therefore have nothing better at his command to assist his reasoning than a pool of still liquid which he could easily overlook, change into any shape, and which he could agitate at one or more points by single or regularly recurring disturbances. By the aid of such he could plainly demonstrate to the eye principles that otherwise would be extremely abstract and difficult of comprehension. The object of the apparatus I am about to describe is to provide, at least to some extent, a pool of this description.

The usual way in which water-waves are shown, is by placing a candle under a shallow tray—some two or three feet each way—with a glass bottom; over it a screen of tissue-paper or fine calico is placed in a slanting position. The water stands in it about an inch or so deep, and when it is touched by the finger, or agitated by a drop of water let fall into it, the waves are projected on the screen. Such a contrivance is not adapted for demonstration before a large number of people, and besides, it must be specially made for the purpose. Having had occasion lately to be in want of some such apparatus in connection with a series of lectures on sound, I was anxious to make one that would show the waves on the surface of a liquid thrown on an upright screen like the slides of a magic lantern, and that would consist of a combination of things usually in the hands of a student or teacher of science, which, for the most part, are

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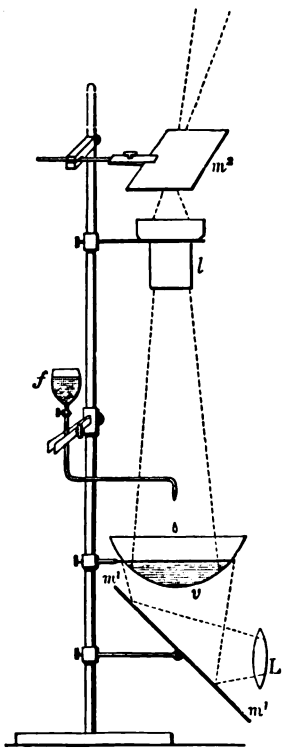
used for other purposes. Having succeeded, at lease so far as I wished, a note of the combination may not be uninteresting to the Members of the Society.

The general features of an apparatus such as I wished to put together must suggest themselves to every one. There must be a magic lantern, L, or something equivalent, to give a strong beam of light; a mirror, m^1, to turn this vertically upwards through the glass-bottomed vessel *v*, filled with liquid; a lens, *l*, to throw the image of the waves produced in this vessel on a screen, and another mirror, m^2, to turn the light horizontal, so that the screen may be vertical.



These, in the combination I use, are all disposed on a long retort stand with the aid of the rings and clamps, which usually make up the full complement of its "fixings," and at distances best adapted to produce the required effect. The upright rod of the stand is nearly 4 feet, though less would do. The lower mirror is 12 inches by 8, and the upper mirror need only be 2 or 3 inches square. The lens employed is a camera lens of 9 inches focal light; but a simple lens would answer the purpose. The waves are excited by a dropping apparatus *f*, of this kind. An ordinary German funnel, provided with a glass stop-cock, is bent twice at right angles, and has its lower end drawn into a fine opening like a pipette, the stop-cock regulates perfectly the frequency of the drop, the point can easily be moved to stand over any part of the liquid, and the drop falls straight down in a line with the end of the funnel. The chief

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novelty in the combination is the shape of the vessel containing the liquid. If a flat-bottomed vessel be placed over the lower mirror it is next to impossible to get it properly illuminated. The surface of the liquid is perfectly transparent and there is nothing to catch the light. Hence, as the light comes in a diverging cone on the bottom, there is nothing to prevent this divergence continuing after it passes through the vessel, and the most of the light in this way falls outside the lens, and is lost. Now, by the simple contrivance of using a glass saucer made out of the end of a glass shade, this divergence is prevented, and all the light incident upon it is made to converge on the lens and to pass on to the screen. The shade is thus, along with the liquid in it, a lens. The curvature of the shade makes all the difference between failure and success. The liquid employed is spirit of wine, which I find to transmit its waves under these conditions somewhat slower than water, and to give a better illumination. The sloping nature of the edges of the shade should make the waves move slower at the outside. The difference is hardly, however, observable; and if it exist it is rather an advantage than otherwise. If the disk were filled, however, and a ring of sheet-metal put in the middle, so as to form the area for the waves, and the shallow edges cut off, this, if thought an objection, could be obviated. The liquid lens is from six to seven inches in diameter, and the disk is cut from a shade whose cylindrical part is ten inches in diameter. When a bright disk is got on the screen the point of the dropper is put about two or three inches over the surface and drop allowed to fall, the course of the waves thereby excited can be traced with marked distinctness on the screen. An Argand lamp is sufficient to illuminate a screen a few feet in size, but when more than that is wanted the lime-light must be employed. In the hall of the Museum of Science and Art, where the arrangement was used, a lime-light was thrown on a square screen of ground glass three feet in side, and the demonstrations could be clearly seen by the audience on the other side in the full blaze of the gas sun-lights. The change of shape of the vessel is easily effected by filling the shade with spirit, and introducing figures of

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different shapes made of sheet-metal, open of course above and below; the waves are stopped by the walls of them, and reflected according to their form. Paper may be pasted on them so as to stop the light passing through the liquid in the space at the outer edge. Figures representing the ground-plan of public halls and the like form an interesting subject for demonstration. The drop may be supposed to be the speaker, and the waves, which may be regarded as visible sound, can be followed in their course throughout the building.

Since devising the preceding arrangement, my attention has been called to the description of an apparatus of a like character by Professor Morton of Philadelphia, and given in the Quarterly Journal of Science for October last. The illumination of the containing vessel which is the great difficulty in the construction, is effected in the American construction by placing a horizontal illuminating lens right under the wave-vessel, and a special arrangement of magic lantern lenses is specially adapted to it. It would thus seem that I could have learned both the difficulties of the exhibition of waves in this way, and the manner of conquering them, from Professor Morton's apparatus. While fully acknowledging the ingenuity and apparent perfect success of his method, there still remains one or two peculiarities in the arrangement just described which may be worthy of notice. In it any magic lantern will do, the wave-exciting apparatus is different, the horizontal illuminating lens and the wave-vessel are united in one in the spirit lens, and there is no special construction needed. It is, besides, cheaper, and a greater latitude appears to be given in regard to the size of the wave-vessel.

Note.—This apparatus was exhibited in action with the aid of a lime light. The pool of liquid was seen projected on the screen at the end of the hall, fifteen feet in diameter, and the propagation, reflection, and interference of waves in vessels of various shapes were distinctly shown.

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On the Manufacture of Toys. By Professor T. C. ARCHER.*

The person who assumes that any occupation which furnishes profitable employment to a number of his fellowmen is beneath his notice, has much to learn. There is no trade however humble, and no manufacture however apparently insignificant, which does not embrace an amount of ingenuity and mental effort which is worthy of respect.

This is remarkably shown in the manufacture of the toys of different countries; and I venture to say that many of these products show so much cleverness that, had the minds of their makers been led to larger and more important subjects, they would have produced grand engineering exploits. The toy trade of Europe, from a money point of view, is one of considerable importance. We import toys to the value of nearly a quarter of a million sterling. In 1870 we received toys from Hamburg to the value of L.57,189; from Bremen to the value of L.46,465; from Holland, L.77,550; from Belgium, L.42,587; from France, L.12,076; and from other parts, L.3012;—in all, L.238,879. And we exported to America and our colonies about L.98,000 of our own manufactures, and of foreign-made toys to the value of L.15,741. Thus we paid over L.200,000 per annum to our continental neighbours for the amusement of our children; and notwithstanding our great manufacturing powers, we contributed less than L.100,000 to the entertainment of the juvenile world abroad. It would be a curious and interesting study to trace out the cause of this, for it involves considerations not apparent at first sight. The productive industry which is able to spare us toys to the value of nearly a quarter of a million, and which probably supplies the rest of the world with at least as much more, is not the work of great manufactories, aided by extensive machinery, but is chiefly the result of habits of industry which lead the peasantry of large portions of Germany to feel a

* Read before the Society on 26th February, 1872.

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pleasure in thus employing their leisure in the long winter evenings. Amongst the countries named as the places of export to this and other countries is Holland, which sends us the largest quantity, and hence such toys as we receive from thence are not uncommonly called Dutch toys. They are, however, not made in Holland, or at least only a very small quantity. They are made principally in the hamlets of the great Thuringian Forest and the agricultural districts of Franconia, especially those in the vicinity of the quaint old city of Nürnberg, to which the toys are brought by the collecting agents, to be packed and transmitted to all parts of the world. The toys made in Franconia are chiefly metal. Paste toys are chiefly made in Saxony; they are cast in moulds. Though cheap, these toys are not in very great favour, owing to their being very easily broken; and their brilliant colours very often tempt children to suck them, to the great and reasonable horror of all parents who have heard of the poisonous qualities of many of the most showy pigments. The leaden toys so well known in this country, chiefly in the form of companies of soldiers on a very rapid march, judging from the extensive projection of their right legs, &c., are chiefly made in Prussia, and perhaps have helped in the military education of that nation of soldiers. They are also made in Bavaria and other places, but the best are Prussian. Of course they are cast. Würtemberg shines in highly finished tin toys. A very superior class of metal toys is made in the city and neighbourhood of Nürnberg, which, from its expensiveness, is not so generally known. I mean the stamped toys which are made of blanks cut out of thin sheet metal, and stamped by leaden weights into iron moulds.

What led me to bring the matter under the notice of the Society was the wish to indicate how ingeniously the Saxon peasants, with a very primitive lathe, make all the animals, or rather representations of animals, which fill those wonderful Noah's Arks which are received in such vast numbers from them, and at prices so low that we are amazed, until we

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know by what ingenious devices they are produced. They are all formed by turning on a lathe. An elephant, a horse, and even those wonderful well-clad Noahs, Mrs Noahs, and their married sons, are all matters of turning. A section of fir wood of the proper size is taken and turned into a ring of varying contour, which when shown in section represents a particular animal, or part of an animal. In that way the arks are filled; and according to the size and number of animals contained in them they vary in price from a penny to half a sovereign. Other toys, such as large soldiers, are also produced by turning, and more pretentious objects, such as vases with rings, which are really masterpieces of the art of turning.

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JUBILEE DINNER

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS.

THOMAS IVORY, Esq., Advocate, President, in the Chair.

GEORGE HARRISON, Esq., and Professor FLEEMING JENKIN, Senior Councillors,—*Croupiers.*

Present—Guests.

W. J. Millar, Esq., C.E., Secretary of the Institution of Engineers and Shipbuilders in Scotland.		By invitation of the President and Council.
Henry O. Bennett,	Guest of	Wilson Hartnell.
James John Cadell,	„	Henry Cadell.
Wm. Baxter Carmichael,	„	Peter Carmichael.
A. B. A. Kennedy,	„	Wilson Hartnell.
John M'Culloch,	„	David C. Mudie.
F. A. Mackay,	„	William Turnbull.
A. Kirk Mackie,	„	Robert Wilson.
James A. Molleson, C.A.,	„	Archibald Hood.
J. J. Muirhead,	„	Bailie Cousin.
James A. Ogilvie,	„	Archibald Ogilvie.
Charles John Pearson,	„	Charles Pearson.
Robert Louis Stevenson,	„	Thomas Stevenson.
David Stratton,	„	E. Elmslie Sang.
Thomas Sturrock,	„	John Sturrock.
James Williamson,	„	Bailie Cousin.

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Fellows.

William John Aitchison.
Professor Thomas C. Archer, F.R.S.E.
William Bell.
Peter Carmichael.
Frederick Hayne Carter, C.A.
John Knox Chisholm.
Bailie George Cousin.
John Cox.
James Craig.
James Jobson Dickson.
Robert M. Ferguson, Ph.D., F.R.S.E.
Alexander Fraser.
Alexander Gowans.
James Gray.
Rev. W. H. Gray, D.D.
George Harrison.
Robert Reston Horne.
Thomas Ivory, Advocate.
Prof. F. Jenkin, F.R.SS.L. & E.
William Lees, A.M.
Alexander Leslie, C.E.
John J. Lundy, F.C.S., F.G.S.
Stevenson Macadam, Ph.D., F.R.S.E.
David J. Macbriar, S.S.C.
Peter Maclagan of Pumpherston, M.P.
Hector Frederick Maclean, W.S.
Robert Matheson, Architect.
F. Suther Melville, Asst. C.S.
Duncan Menzies, Architect.
John Milne.
John Kolbe Milne.
William Lambre Moffatt, Architect.
John Scott Moncrieff, C.A.
Adam Mossman.
David C. Mudie.
William Hamilton Muir of Shawhill.
Heinrich Wilhelm Nachot, Ph.D.
Archibald Ogilvie.
John Paterson, C.E.
Charles Pearson, C.A.
David Bruce Peebles.
William Alfred Roberts, M.D.
John Russell, Lord Dean of Guild.
Edward Sang, F.R.S.E.
Edward Elmslie Sang, C.E.
Robert M. Smith, F.R.S.E.
Thomas Stevenson, C.E., F.R.S.E.
John Sturrock.
Archibald Sutter, C.E.
John Wardrop Tawse, W.S.
James Tod.
John Tod.
William Turnbull, F.R.S.E.
Alexander Wallace, A.M.
John Kippen Watson, F.R.S.E.
James T. Wilson.
Robert Wilson.

The following gentlemen, Fellows of the Society, who had intimated their intention to be present, were unavoidably prevented:—

Henry Cadell, Vice-President.
David Chisholm.
James Davidson, M.E.
Alexander Gray.
Archibald Hood.
Walter Macfarlane.
David Marshall.
John Miller of Leithen, M.P.
Hugh Morton.
Professor Macquorn Rankine.
John Reid, Vice-President.
Thomas Rowatt.
David Smith, F.R.S.E.
James Tod, Advocate.

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And the following gentlemen sent letters of apology:—

Richard Adie.
John Archibald, M.D.
Robert Aytoun, W.S.
Sir David Baxter of Kilmaron.
J. L. Boyd, S.S.C.
D. R. Brown.
Frederick de Chaumont, M.D.
David Cousin, City Architect.
Charles Cowan of Beeslack.
Alexander Cunningham.
Heriot Currie.
James Falshaw, C.E.
Robert Ferrier.
Wilson Hartnell.
J. Stewart Hepburn of Colquhalzie.
Robert Horsburgh.
Richard Hunter, H.E.I.C.S.
William Johnstone, C.E.
William B. Kirkwood.
James Mackenzie.
Professor Douglas Maclagan, M.D., F.R.S.E.
James M. Melville, W.S.
W. J. Cockburn Muir, C.E.
Alexander Reid.
Professor William Swan, F.R.S.E.
Arthur Trevelyan of Pencaitland.
John Whitehead, S.S.C.

The chair was occupied by Thomas Ivory, Esq., Advocate, President of the Society, supported on the right by W. J. Millar, Esq., C.E., Secretary, and representative of the Institution of Engineers and Shipbuilders in Scotland; Dr H. W. Nachot, as one of the Senior Members of the Society; Professor Archer; John Cox, Esq. of Gorgie House; James Tod, Esq.; John Scott Moncrieff, Esq., C.A., the Treasurer, &c.,—and on the left by James Gray, Esq., Great King Street, Senior Member present; Rev. Dr W. H. Gray of Lady Yester's; Bailie George Cousin, Councillor Muirhead, Dr Stevenson Macadam, &c.

In the absence of the Vice-Presidents, the Croupier's chair on the right was occupied by George Harrison, Esq., supported by Peter Maclagan, Esq. of Pumpherston, M.P.; and that on the left by Professor Fleeming Jenkin.

Grace was said by the Rev. Dr Gray, and after dinner,

The Secretary intimated that he had received apologies from members who were unable to be present, and also from some who, having meant to be present, were unavoidably prevented. Among the latter there were from David Rowan, Esq., President of the Institution of Engineers and Shipbuilders; from Professor Macquorn Rankine; from Henry Cadell and John Reid, Esquires, the Vice-Presidents,

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who were both prevented by sickness,—all of whom had intended to take part in the proceedings.

The CHAIRMAN, in proposing the toast of "Her Majesty the Queen," said—There is no period in the history of our country in which the throne has been so worthily filled as during the whole reign of our beloved Queen, or when, by consequence, the feelings of devoted loyalty and warm personal attachment to the Sovereign have been so strong. And there has been no time during the present reign when those feelings have been exhibited in greater intensity than during the recent days of sorrowful anxiety. I give "The Queen, and may she long and happily reign over a free, loyal, and an attached people."

The toast was drunk with all the honours.

The CHAIRMAN then gave "His Royal Highness the Prince of Wales and the rest of the Royal Family," in support of which he said—The whole nation rejoiced on Monday last to see from the announcement of the bulletin of the previous day, that all cause for anxiety in regard to the complete recovery of His Royal Highness the Prince of Wales had passed away. I give you the toast, "The Prince of Wales, may he be speedily restored to complete health," and with this I conjoin, "The Princess of Wales and the rest of the Royal Family."

The toast was warmly responded to, and was drunk with all the honours.

The CHAIRMAN then gave "The Army, Navy, and Reserve Forces," which was heartily responded to.

The CHAIRMAN then rose to propose the toast of the evening, "The Royal Scottish Society of Arts," in support of which he said—It is now my pleasing duty to propose "Prosperity to the Royal Scottish Society of Arts." In proposing this toast on the occasion of the Society having completed the fiftieth year of its existence, it is natural and fitting to take a retrospect of its past career, to consider its present position, and to look forward to its prospects for the future.

There are now living only three of the original members of the Society; these are the Duke of Buccleuch, the Duke

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of Abercorn, and the Marquis of Tweeddale. There are no members present who can remember the foundation of the Society, nor, with the exception of our Secretary, any who can remember its operations during the years of its infancy. I have, accordingly, thought it would be not only appropriate to the present occasion, but acceptable and interesting to the members present, to give a short notice of some of the most salient points and most interesting facts connected with the history and working of the Society.

As is the case with many other celebrities, it is impossible to fix precisely the date of its birth or foundation. The only data for approximately determining this which I can find, are two documents,—the first, a printed prospectus of the Society of Arts, bearing date June 1821; and second, the earliest minute extant of a meeting of the Society, dated July 1822. But whatever may be the uncertainty as to the exact date of its foundation, we know that it was originated by Dr, afterwards Sir David Brewster, one of the most distinguished of mechanical philosophers, and of whom not only our Society, but Scotland, is justly proud; and that it had for its object, as announced in the prospectus dated June 1821, "The encouragement of the mechanical arts in Scotland:—1. By awarding prizes to the authors of useful inventions or valuable processes; 2. By assisting inventors in securing the just reward of their labours; 3. By performing useful experiments or making trials of machinery when the inventors themselves have not the means of carrying their ideas into effect. It consisted at first of 157 members, embracing all ranks and classes of the community,—the king as its patron. Among the original Scotch members I find three dukes, four marquises, four earls, and one viscount; then the Justice-Clerk, and a great many of the then judges, the Lord-Advocate and the Solicitor-General, besides almost all the distinguished citizens of the day,—I may mention Sir Walter Scott, Sir Thomas Dick Lauder, Sir Henry Raeburn, and Francis Jeffrey. It began to publish its transactions in 1829, and was incorporated by royal charter in 1841 as the Royal Scottish Society of Arts.

Its first place of meeting was in the rooms of the Royal

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Society, and next in those of the Antiquarian Society, in the Institution on the Mound; it made five different subsequent removes before 1863, but in that year it took possession of its present hall, which it had built for the purpose.

As early as 1825 I find a recommendation by the Council of the Society, which was adopted at a general meeting, and directed to be carried into effect,—"That there should be an annual or biennial exhibition in Edinburgh of inventions and of the productions of domestic and foreign industry to be held in Edinburgh during the month of May." This shows that our Society was among the first to recognise the great value of National and International Exhibitions, and to suggest their organisation.

Again, among the prizes offered at the very outset by the Society was one "For the best plan in point of economy and salubrity for heating and ventilating applicable to common town dwelling-houses," and another "For the best set of experiments on preserving meat by salt; the account to specify the chemical changes and combinations which take place during the process, and to show the causes of the variations in the results of the ordinary processes." Then a few years later a prize was offered "For the best apparatus and mode of printing for the use of the blind," which called forth a number of valuable papers, and an able report on them by the late Mr William Fraser.

Among the many valuable inventions and papers submitted to the Society in its early years it may be interesting to note a few of the most prominent.

A latch-lock by the Rev. Mr Brodie of Monimail, which, I am informed by our Secretary, is identical with the famous Chubb's lock, not patented till long afterwards.

The stern-paddle or screw-propeller, invented by Mr Robert Wilson, now of Patricroft, with which actual experiments were made at the expense of the Society, being among the earliest in this country.

As early as 1828 I find a paper on street-railways, which have only recently been adopted under the name of tramways.

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In 1829, there is a paper by Captain M'Konochie, R.N., on steam-towing as applicable to mercantile navigation; then there is the very valuable holophotal arrangement of light-house lenses, invented by Mr Thomas Stevenson, one of our fellows. A paper by our secretary, Mr Sang, accompanied experiments exhibited by him, illustrating the rotation of the earth, which were eighteen years prior to the paper by Foucault, covering precisely the same ground, which excited so much interest in the scientific world. Mr Sang, of course, put forward his claim to priority, which was conceded. Lastly, I would mention the valuable papers by Sir John Robison and also by Dr Fyfe, on the best means of burning gas for supplying heat, and the paper by Sir John Robison on the best mode of burning it for the purpose of illumination. It may, perhaps, be of interest to add that many valuable and interesting communications were made by Mr James Naysmith of steam-hammer celebrity, and by his brother George.

It may be well to point out a few particulars as to the working of the Society. The laws and practice give to the Society complete control over every action taken in its behalf, the Society's minute-book, and even that of the Council, being open to the inspection of Fellows.

The Society does not attempt to control the course of invention, but merely seeks to reward and assist communicators, whether these be members or strangers.

It submits communications to the judgment of responsible committees selected from those among its members best qualified to report upon them, and at the end of each session places the whole of the communications before an openly-appointed prize committee.

Since 1836 ten prizes annually on an average have been awarded; the largest number in any year having been *twenty-one*, and the lowest *three*. This helps to show how useful the Society has been in eliciting valuable communications and inventions, and thus promoting the improvement of the useful arts.

A few words now as to the place and value of the Society at the date of its institution, and generally in times past.

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In order to a correct appreciation of this, it is necessary to bear in mind the immense difference in many most material respects between the times in which we now live and those in which the Society was instituted. Invention had not then taken the great start which it afterwards took, nor assumed the commanding position which it now occupies. Great inventions then came out at long intervals, and progress in the useful arts, which previously had been measured by centuries, even then was measured by generations; and this slow progress is easily accounted for, when we consider how different was the state of matters in our own country and throughout the world, in many most material particulars, at the time our Society was founded, from what it is now.

Consider, for instance, the expense and other difficulties attending the old patent law, the want of rapid intercommunication between the different centres of manufacturing industry—steamboat navigation was then in its infancy, our present system of railways was then unknown; then again, the want of rapid intercommunication between mind and mind, for in those days it took as long to get a letter from London delivered at a place five miles distant from it, as now at a distance of four or even five hundred miles. Still further, till within the last forty years we had no penny post, no telegraph, no provision by means of cheap daily newspapers and numerous periodicals devoted to science and the useful arts, in Scotland, and hardly any in England, where inventors had an opportunity for describing their inventions.

It was before any of these facilities or encouragements were afforded to inventors that our Society was founded; and its success from the moment of its foundation amply demonstrated the sagacity and far-sightedness of its originators. I am assured by our Secretary, who was admitted a member of the Society in 1828, that its success was complete, and that it gave a great stimulus to the development and progress of the useful arts in Scotland; it will, I am sure, be interesting to have noted a few proofs of this, and I might have easily noted more, but as our invaluable Secre-

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tary, Mr Sang, is present, who has for upwards of forty years been a member of our Society, I have thought it right to leave it to him to tell us in more detail something of the history and of the progress of our Society in its earlier years.

Coming to the consideration of the present position of the Society, it is fortunately unnecessary for me to say more than a few words, for I am speaking to members who are able to testify of their own knowledge how important is the place still filled, and how valuable the work still done, by this Society. Of course it does not now fill the same relative place in regard to the useful arts which it did when first instituted. Then, as I have already indicated, our Society was practically the sole medium through which inventors in Scotland could make public their contrivances and suggestions of improvements. In the present day there are a multitude of channels open for this purpose. The last Patent Law, with all its faults, the cheap press, and many societies for the cultivation of special branches of science and arts, afford almost all the encouragement and stimulus possible to the progressive development of the useful arts. This is all true; but it is still no less true that our Society still holds one of the foremost places in Scotland among the means of encouraging and developing these.

A reference to a very few of the important matters which have recently been the subjects of papers submitted to the Society will demonstrate this.

The illumination of beacons by electricity; safety-couplings for railway carriages; safety-clutches for hoisting apparatus in mines; the disposal of sewage and the drainage of houses and towns; the supply and distribution of water; water-meters; and improvements in the manufacture of gas—all testify to this. Nor must I omit the important conference on the subject of technical education recently held in our rooms.

Our members in 1822 were 157; their number now amounts to 400.

Before passing from the consideration of the present position of the Society, there is one point deserving of

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separate and special mention and congratulation. I allude to the state of our funds. If in other respects our relative position be not so high as it was at first, it is far otherwise as to our funds. In 1825 they amounted to only about L.300. In 1839, when our present invaluable treasurer was elected to the office which he has ever since held, they had risen to L.1340; now, by his careful management, that sum has been more than doubled.

As to the future, I believe that there is a career of usefulness for the Society as great, at least, as at any previous period of its existence.

With this toast I would couple the names of our oldest member present, our valued and indefatigable secretary, Mr Sang, and our oldest official present, our most able and efficient treasurer, Mr Scott Moncrieff.

With regard to Mr Sang, I will not speak of him in his presence in those terms of high praise which I would freely use in his absence, not only because I know it would be distasteful to himself, but because the mere statement of a few facts taken from the records of the Society, to which he cannot object, will speak more powerfully in his praise than could any eloquence of mine.

He was elected a member on the 5th March 1828, and is, with the exception of the three noblemen already named, and of our valued member and contributor, Mr Robert Aytoun, the oldest member of the Society. On the 7th May of that year he read a report, for which he received the thanks of the Society, and at the same time he was put on the Committee for drawing up the Laws. Ever since that time there has not been a more active or useful member and promoter of the Society than Mr Sang. The communications which he has made have not only been of great value, but surprisingly numerous. I am sure I am within the limits when I say that he has contributed at least one paper for every year of his residence in Scotland. He has had awarded to him the highest prize at the disposal of the Society, the Keith prize of 30 sovereigns, besides many of its other prizes. Of his labours since he has been secretary I need not speak, as they are well known to all here.

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As to our highly-esteemed treasurer, Mr Scott Moncrieff, I will only say that it is to his unremitting exertions and judicious management that our funds are in the very prosperous state already mentioned. He was elected treasurer in 1838, and has since discharged the duties of the office in a way which has excited the admiration of all who have been brought into contact with him. I have asked him to be so good as favour the members present with a concise narrative statement of the funds, as at the date of his election and now. I give "The Royal Scottish Society of Arts, coupled with the names of Mr Sang, our oldest member, and of Mr Scott Moncrieff, our oldest official present."

The SECRETARY, Mr Edward Sang, returned thanks for the kind manner in which the chairman had spoken of him, and for the flattering reception of that mention by the members. Gladly escaping from the merely personal part of the matter, he proceeded to observe that the president had expressed a hope that the meeting would hear from the secretary some details of the early history of the Society. For this, he said, there are good grounds, seeing that he had been connected with the Society from a very early period, and had during all that time never once missed being present at the meetings except when residing abroad; so that, if his memory were good, he ought to have been able, even to tiresomeness, to give a very full account of the Society's doings.

It is exceedingly cheering to see here assembled so many of the members, giving promise of long-continued prosperity to the institution; at the same time, there was sadness connected with the thought, that of all who had welcomed him to the Society, not a single member was here to rejoice with him on its jubilee. The only one who could have done so, our venerable friend Mr Robert Aytoun, being prevented, not by ill-health, but by precautionary considerations incident to age, from being present. Mr Aytoun had verbally expressed his regret at not being able to attend with us.

Of the original members of the Society, the names of only three remain on our list. These are the Duke of Buccleuch, the Duke of Abercorn, and the Marquis of

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Tweeddale, none of whom, however, have ever taken any part in our proceedings.

Our next member in seniority, Mr John Miller, of Leithen, has, to our great regret, been unable to join us; but we are glad to see still among us, worthily supporting the chair, our old and most respected fellow, Mr James Gray, who at an early period contributed to our proceedings papers on locks and safes, and whose name was long a household word among us. We are also favoured with the company of the next member on our list, Dr Nachot, who, though he did not communicate papers, was distinguished for the lively interest taken by him in all our proceedings.

For several years the Society was in a state of torpidity, without regularity, without laws, almost without life, till, in 1826, Messrs Robert Aytoun and James Tod, both Writers to the Signet, were appointed joint secretaries. Under their auspices laws were framed, and ever since the proceedings of the Society have been regular. Our worthy chairman, in noticing what efforts had been made at the outset, has omitted to mention the debt which the Society owes to the legal profession. In fact, our main support in the early stages of our existence was received from advocates, writers to the Signet, solicitors, and accountants, with a few amateur mechanicians. Not until the Society was fairly set on its feet did it receive support from more than a very few of our engineers, and professional men of that class. It is, therefore, with the greatest pleasure that, on this occasion, we see the presidential chair occupied by a most respected member of the bar.

The laws of the Society were not arranged without lively discussions, which, as in many other cases, took as issue the question of close or open management. We had meetings, special meetings, and adjournments to settle the vexed questions—the result being in favour of perfect openness. Of our secretaries, Mr Aytoun took the side of open, Mr Tod that of close management; but when Mr Tod came to be sole secretary, he most loyally carried out the views of the majority, just as if they had been his own; and after-

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wards, by experience of their working, came to admit their soundness. We could hardly say anything bearing a stronger testimony to Mr Tod's high principles, unless, indeed — what we must say — that to his perseverance, urbanity, and energy, the Society stands indebted for the position to which it has attained. Though not connected in business with the useful arts, Mr Tod was an enthusiastic student of them.

The order introduced by Mr Tod into the procedure of the Society has been so effective, that its history is now completely written in its Minutes and published Transactions, and instead of tiring you with remarks on these, I shall venture to offer you a few thoughts on the position of the arts themselves.

Our first title was "The Society for the Encouragement of the Useful Arts in Scotland." I confess my partiality for that title.

It has long been, perhaps it ever will be, the fashion to condescend to the useful arts,—to place results above their causes. Painting and sculpture pass us by; they are the fine arts. Poetry ventures to afford us an occasional glance. History, engaged in recounting wars and turmoils, hardly spares a few lines to our unobtrusive progress; and science, with many excuses for so far lowering herself, now and then reaches us her left hand. We are yet knocking timidly at the door of national education for admittance to its lowest form. Nobility is in the foray or the battle-field. Who would dream of such ridiculous titles as Duke of the Anvil, Marquis of the Steam Engine, Viscount Steel, or Baron of Water-leaf? Yet these despised useful arts occupy the high position of being the nurses of all that is good or noble in humanity.

Look back to the infancy of the race, when men had hardly learned to plait grass for garments; to defend themselves against the beasts with clubs broken from the trees and trimmed by friction against rough stones; when they tore the skin from the carcase with their teeth and nails, to wrap it round their limbs. Fancy how, in mid-winter, men ventured from their hiding-place, with aching fingers and

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frosted toes, to gather scanty food from behind stones or from clefts in the rock, and crunched the luscious molluscs with their teeth; and consider how completely man's energies were then absorbed in the struggle for very existence, how exclusively his thoughts must have been fixed upon himself.

Slowly he learned, in terror of each succeeding winter, to store up nuts and sun-dried fruits, to cultivate the ground by means of crooked trees, and slowly the ideas of labour, of property, of justice, were formed. Man began to possess a little leisure; barter sprung up; splintered bones served as knives to trim the shaggy dresses, neatness, even elegance, came to be studied; and this, to us, rude state of society had its appropriate code of laws and morals.

Just as we have been astonished by the inventions of the steam-engine, of photography, of telegraphy, so, but much more intensely, was primitive society shaken to its very foundations by the splintering of a flint. A new era dawned upon mankind. Men were now able to overcome difficulties previously insurmountable; new arts arose; stone-barbed javelins and arrows subdued the animals; cutting and boring tools gave rise to carpentry; spear-shafts were carved with elaborate devices, and sculpture had her rude beginning. With more time for thought, new ideas filled men's breasts; old laws were forgotten; morality assumed a new phase. Nor were these changes effected without trouble; the flint-bearers became warriors, to subdue the neighbours, and not courage, but art, established the victory.

Again, the discovery of fire convulsed society; art after art has arisen from it, and even yet, though its origin be lost to us in remote antiquity, we are only beginning to develope its influence; scarcely a single improvement in the position of man has been made without its help. Previously liable to all the diseases incident to the use of raw food, man found his health, his strength, his stature improve, and, with new occasions for its exercise, his intellect grew apace. Wielding now an almost miraculous power over the material world, he proposed and executed

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works before unthought of. The fire-bearing tribes overran and oppressed their fellows, yet carried with them the living seed of future progress.

Fire gave to us pottery, glass, lead, tin, copper, bronze, iron, steel, each to make its mark on the course of human progress, each to create new ideas, new tastes, new pursuits.

The useful arts minister to our material welfare, they have regard to the animal, not to the intellectual part of man; their objects are sordid, low, mean,—they are of the earth; their cultivators are mere mechanics, smiths, carpenters, stone-hewers, following trades, but not professions. Let us weigh the matter.

The brave soldier who has thrown himself against the enemy regardless of danger, seeking only the success of his cause, has done an act of heroism, his name is celebrated, and his honours are but too dearly won. When gentle peace shall have spread her mantle over the whole earth, shall heroism have been extinguished? Hark to the crash! The fire-damp has exploded—the mine is in ruins—the wail of mothers and wives and children resounds! See to the noble miners, venturing, baffled, returning, persevering, perishing in the attempt to save their fellows! Is there no heroism here? Can no poet find here a theme for praise?

Look to yon sharp rock far off in the western sea, where the waves break without ceasing, where many a stately bark has foundered. A few men land, they ply the hammer, with toil and amid danger they rear the slender scaffold; then week by week the fabric grows until the granite tower rises high above the tide. Is there here no bravery? And now the lantern glitters in the setting sun. Through lens and holophote the seven-wicked lamp sends forth its blaze, twinkling like mercury in the twilight, and, as the darkness grows, growing in brightness. Think of the lonely keepers, when from the south and west the tempest comes, wave heaping upon wave until the stone tower trembles, and rocks beneath the blows. Yet still the light shines on, night after night, flashing in measured pauses its warnings seaward. Thousands who have faced the cannon's

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smoke, and heard with unblanched cheek the whee-whee of the bullet, would turn aghast from such continuous daring. Is yon a light far in the midnight west?—'tis white, 'tis red, or red and white together. The keeper turns his binocular upon it, and watches its double tints. It slowly nears, then bends away; one colour only shines; and his heart swells when he thus knows that the skilled captain of the passing bark has found his course to anchorage and safety. Tell me if the mild arts of peace furnish no themes to awaken the deepest sympathies of man.

The snorting steam-horse streaks the landscape with the smoke of his nostrils, scatters fire from his hoofs, screams to far-off echoes the voice of his warning, plunges into the very bowels of the earth, and emerges to vanish in mere distance.

Pass we to the quiet room where the visitor silently traces his cabalistic marks. Within an hour or two the bank of the Hooghly is alive; bundles of raw silk, tusks of elephants, spices, teas, are hurried on board of the expectant ship. Almost as soon the docks at Liverpool are lumbered with bales of calico, boxes of cutlery, and all the endless etceteras of commerce; steam cranes lower them into the hold, and simultaneously the ships depart, each with the return cargo for the other.

Search the whole realms of poetry, and find for me, among the wildest dreams of the greatest dreamer, anything to match the wonder of these realities. This fair earth, once boundless in its flat expanse, grew to be round; with difficulty and with distrust, aye, and with danger, too, men learned to think of, to believe in their antipodes; a voyage round the world was a world's wonder. But now it is as if this earth-ball had shrunk to nothing; those whose feet are opposed to ours have become our neighbours; we learn their doings of but yesterday.

It is not yet three hundred years since Galileo yoked science and art together in the pursuit of knowledge, and made them one. In that short time the experimental method has realised a progress many and many times greater than had been made by all the previous generations of mankind.

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Turn we to astronomy, the most sublime of all the sciences; there the telescope, the divided circle, the chronometer, have converted a few shining points, wanderers among the stars, into so many worlds of the same structure as our own; each with its poles and equator, its day and night, its summer and its winter. Think of four-mooned Jupiter a thousand times larger than this earth; of Uranus, of Neptune, fifty of whose years would outrun the whole range of authentic history; and dream that each is peopled with its appropriate tribes of animated beings.

Turn we, on the other hand, to the science of biology, to the wonders revealed by the microscope, to living beings smaller than the dust that floats in the sunbeam, and judge of what a universe the arts have unfolded to our view.

Of all the wonders in this wondrous world there is none that strikes us so forcibly as this, that a small speck of dust creeping upon one of the smallest planets, whose longest is not a year of some, should raise its thoughts to grasp this vastness—should imitate, and, in its own small way, create arrangements.

The iron elephant, without fatigue or pain, turns the huge fly-wheel; regulates the supply of air and water to its own requirements. Then the beaters crush and tear the flaxen fibres till the smooth pulp flows o'er the ledge. The ever-growing sheet progresses, dropping its surplus moisture by the way, to climb upon the cloth-clad drum, and thence to pass through tanks and drying stoves. Next come the inking-rollers and lettered cylinders, and on both sides the web presents its lettered pages. The quick knives separate the sheets, the folders double and redouble, till at last forth comes the finished book, that contrivance by which the thoughts of one becomes the thoughts of thousands.

Yet the exquisitely carved shell of the minutest diatom reveals arrangements and contrivances infinitely beyond all that man has done or ever can do; and we place our hands upon our mouths, our faces in the dust, in presence of a wisdom that we cannot begin to comprehend, of a goodness that overwhelms us.

Let us then continue to lend our feeble help to the

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advancement of the useful arts, certain that thus we shall assist in developing the noblest interests of mankind.

Mr J. Scott Moncrieff, the Treasurer, in responding also to the toast, said—I think we may congratulate ourselves on the success which has attended the Society. When I was first honoured by being elected its treasurer, which was in 1838, the number of members was 264, while last year they amounted to 398, being an increase of 134. With regard to the funds, in 1839 the general fund of the Society amounted to L.926, 18s. 3d., while in 1870 the amount was L.2053, 7s. 5d., showing an increase of L.1126, 9s. 2d. As to the special prize funds, there has been an increase of L.1000. However, I do not think that we should congratulate the Society on the increase of these funds, at least in so far as that increase has arisen from unexpended income, as it certainly would have been better had the number and excellence of the communications sent to the prize committee been such as to have called for an acknowledgment in the shape of prizes equal to the annual revenue arising on these funds. There are four such special funds—namely, the Keith Bequest, the Reid and Auld Bequest, the Brisbane Bequest, and the Hepburn Prize Fund. I find that during the last thirty-five years 341 persons have received prizes, being an average of nearly ten each year; while a great number have been awarded, and I hope have received with a due sense of the honour, the "thanks" or "special thanks" of the Society. In 1839 the Keith Prize Fund amounted to L.414, 4s. 8d.; in 1870 to L.1087, 6s. 8d.; increase, L.673, 2s. The Reid and Auld Prize Fund was received by the Society in August 1851, and amounted to L.163, 8s. 2d.; in 1870 to L.448, 16s. 3d.; increase, L.285, 8s. 1d. The Brisbane Prize Fund was received in 1856; it consists of L.175 consols, and amounted in 1870 to L.172, 13s. 9d. The Hepburn Prize Fund, received in 1862, consists of L.110 of the Scottish Central Railway Stock, and amounted in 1870 to L.163, 17s. 4d. The total value of property and funds under charge of the Society at November 1870, was L.3935, 6s. 7d. I have to thank the Society for the renewed confidence they have from year to year placed in me. I was for many years con-

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joined with their valuable secretary, the late Mr. James Tod, and also with the late Mr. Beatson Bell, during the time he filled the office of secretary, and I have much pleasure in acting along with Mr Sang, our present secretary.

Dr Stevenson Macadam said—I rise, in the absence of our distinguished vice-president, Mr. Henry Cadell, to propose for your acceptance the toast of the "Kindred Societies." We have a number of such societies in England, but there is just one other Society of this kind in Scotland, and that is the Glasgow Institution of Engineers and Shipbuilders. In the welfare of these kindred societies we must have a special interest, for we were among the first who represented and stood up for the application of science to the arts and manufactures. During the first year in which the Royal Scottish Society of Arts was organised we had a council in Edinburgh, but we arranged that there should also be a branch council of our Society in Glasgow, and that branch council was in communication with the Edinburgh council. Let us, therefore, hope and take credit that though a number of years intervened between the branch council of our Society in Glasgow and the establishment of the Glasgow Institution of Engineers, that the impetus which we then gave by our branch council in Glasgow was the first seed which ultimately gave birth to the Glasgow Institution of Engineers and Shipbuilders. There can be no doubt that in Glasgow they have a larger field for the application of science to the arts and manufactures than we have in Edinburgh. Still, we must take credit to ourselves for being the first who perceived the advantages of this; and while we wish such kindred societies every success, let us ask them at the same time to acknowledge us as the father of them all. He added that he had intended coupling with the toast the name of Mr Millar, the secretary of the Glasgow Institution of Engineers and Shipbuilders, but regretted that that gentleman had been obliged to leave in order to reach Glasgow that evening.

Mr Sang (the Secretary) said that Mr Millar, before leaving, had placed the following reply in his hands:—"Our

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Institution, which has been so specially mentioned, endeavours to promote the advancement of the practical appliance of science to engineering and shipbuilding, and by means of the papers read, and the discussions which follow, to spread the information elicited throughout its members. The Institution was founded in 1857, and incorporated in 1871. Its membership is now nearly 400. As representing the Institution at the celebration of a marked period in the history of your Society, I have to thank you for the honour done to our Glasgow Institution and to the kindred societies throughout the kingdom."

Mr J. Cox, in proposing the "School of Arts," after a few humorous introductory remarks, said :—For fifty years it has formed a centre of interest for all who have been concerned in the promotion of the Arts in Scotland, and has been rendering services to the community the value of which can scarcely be over-estimated. It existed as an admirable school for technical education at a time when the very name was scarcely known elsewhere in Great Britain. It is of more value now than ever, when we consider the movement that is afloat among our working classes for higher wages and shorter hours of labour. Unless these classes receive a better technical instruction than hitherto, they will fall behind their compeers in other countries, and we shall be unable to compete successfully with foreign nations. It is of the utmost importance to get our working men to attend these classes; and I would advise every firm—and no firm, I think, will in this case refuse—to subscribe one guinea to the funds of the Institution. By doing so they will have the privilege of sending one pupil to the School of Arts, and in this way they will get ten times the value of their money. Now, when the question of technical education has assumed a form and magnitude which gives it the position of one of the foremost questions of the day, let us hope that the modest precursor of those numerous technical colleges which we hope soon to see founded, will not fail to receive due appreciation and encouragement. The humble building with which we were all so familiar, has become a thing of the past, but we may confidently hope that in its new and improved form the

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School of Arts will long flourish in even greater usefulness, and enjoy a still wider fame than during the first half-century of its existence.

Dr Stevenson Macadam, in replying, said:—During the half century that the School of Arts has been in existence it has taught one thousand pupils every year. It is the second educational establishment in Edinburgh—only coming after the University itself. It was, at one time, the only technical college in the country, and it is now the best school of the kind in Great Britain. I rejoice at the future prospect that is before this really useful Institution. The differences between the directors and the Improvement Trust have been satisfactorily adjusted; and by the liberality of the Commissioners a new building, with larger lecture rooms, and on a very good site, will be erected. I trust that the new Institution, when it is opened, will advance with much greater prosperity than heretofore. To do so we must have the sympathy of the people, but that, I need hardly say, has already been secured.

Mr Thomas Stevenson, C.E., proposed the next toast—"The Arts, Manufactures, and Commerce," which was, he said, in other words, "The Prosperity of the whole habitable Globe." We are quite familiar with the fact that the Legislature has ever and anon occupied itself with the consideration of such subjects as Arts, Manufactures, and Commerce. But our Legislature can only deal with what *already exists*—it can only endeavour to expand and increase what is already in existence. That is an important thing to keep in mind; and there is therefore no more pressing question than this—How shall we create something new in art, manufacture, and commerce? There is only one direction in which we can look to accomplish that, and that direction points to science alone. Therefore, I think it is the duty of Government to do all it can to promote science, in the way of assisting more liberally our Universities and scientific societies. There are some branches of science that require greater assistance than others, for some are self-sustaining, and others are not. At the close of last century we had a science which was in its infancy—I mean galvanism and

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electricity. If the Government of the day had then come forward and fostered this infant science, I venture to say that it is extremely likely we should have had our electric telegraphs half a century sooner. At the present moment we have a science not yet fully developed; I refer to meteorology. This was at one time considered one of the most visionary pursuits in the world, and yet what great things has it not done within the last few years. What, for example, have Maury's Charts done for commerce? Take one instance alone. In the voyage from England to Australia and back, there has been a saving of time effected by means of these charts of something under three months; and a saving of capital to the United States has been effected since 1854 of not much less than L.500,000 by the same means. I hold, then, that our Government, and every Government, ought to promote such sciences as are in their infancy. I am glad to say that a large sum has been put by our Government at the disposal of the London Meteorological Society; but let it not be forgotten that we have a Meteorological Society in Scotland. Our Scottish society has its stations extending from Iceland to the Holy Land, and furnishes regularly to the Government important information. How much annually does it receive in acknowledgment of such services? Not a single farthing. He concluded by giving the toast of the "Arts, Manufactures, and Commerce."

In responding to the toast, Mr George Harrison said:—In the very suggestive address with which our late president, Mr Thomson, opened the present session of our Society, he told us that we had little reason to expect in the coming half century any such important discoveries as had characterised the past half century, but that it was exceedingly probable that the application of the sciences would be carried to an extent of which no man living could dream. I have no fear whatever, whether it be furthered by Government or by the wealth of private persons in this and other countries, as to this great progress being realised. Scotland, they might be sure, which sent out more educated emigrants, more pioneers of science in comparison to its

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population than any other country, would have a large share in this glorious future. Of this we may be proud, that Edinburgh merchants had always maintained a high character for that which alone can give a solid basis to industry, commerce, and manufactures—namely, high honour and strict integrity. If this character of the metropolitan merchants represented that of the country at large, we might rest assured that Scottish arts, commerce, and manufactures would continue to prosper in the future as in the past.

Dr FERGUSON then gave "The Universities of Scotland." I do not think I have to go far to find a connection between the Society and the University. One of the great founders of our Society, Sir David Brewster, filled successively the office of Principal in two of our Universities. In times gone by the Professors of the University have exercised a most powerful influence on the history of the Society. I joined our Society when the late Professor George Wilson was president, and no one can forget the genial influence exercised by him over our meetings. After him we had our astronomer-royal, Professor Piazzi Smyth, who combines in a rare degree the accuracy of the scientific man with the enthusiasm of the poet. Our connection with at least our own University in this way has by no means ceased, for we still reckon several Professors among our most active members. Another good reason for remembering the Universities on such an occasion is this, that they have contributed directly to the material advancement of the country. Free trade and the steam-engine, the moving powers of modern commerce, are in their origin intimately connected with them. It is not to be expected, venerable as the Universities are, that they will escape that criticism which, in this age, is brought to bear upon all institutions. There are several vexed questions at present before them which are exciting a good deal of interest and keen feeling. One important question is that of free trade in education. In Germany there is a considerable amount of free trade in University education, and, notwithstanding, the true position of the Professors is in no way affected. In a German University the Professor is only one, but the most distin-

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guished one, of a body of recognised lecturers on the same subject. There a promising young student finds a graduated pathway by the lectureship to the eminence of the Professor; and why should the same open career be closed to the promising young Scot? However these and other questions may be decided, Scotchmen will be agreed in this, that the Professors of our Universities should always occupy a dignified and important position.

Professor FLEEMING-JENKIN replied. He said:—The honour which has been paid to the Universities of Scotland gives especial pleasure, coming from a body mainly interested in the practical arts. It proves that the Universities are already looked upon as directly connected with those arts, and that the leading practical men look to the Universities as the proper sources of the high scientific knowledge which is now required by those who aspired to success as engineers, manufacturers, and merchants. Fifty years since, the learned scholars of a University probably looked down with complacency on those who followed what they in their hearts thought base mechanical crafts. In the present day that is impossible; we have got past that time. These mechanical crafts take their stand, and proudly, by the side of the learned professions, and our Universities have not been backward in recognising that fact. To-day, the mechanical crafts require as thorough a training in knowledge of as lofty a kind as the most learned of the old learned professions. The arts are always willing and proud to acknowledge the debt they owed to science. The teachers of science, on the other hand, ought never to forget the practical bearing of their investigations; and although it is most essential that many men of science should pursue abstract investigations without the smallest regard to practical results, nevertheless the great teaching bodies, the Universities, are bound to supply the technical instruction by which the results of pure science are made to promote the advance of arts and commerce. This truth the Scottish Universities have not been slow to acknowledge. They have gladly instituted new chairs for teachers of the applied sciences, they have created new degrees in science, and con-

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fer honours with equal readiness on students of the newer as on students of the older form of learning. I can testify, from personal experience, with what perfect cordiality the new branches of study are welcomed. Much remains to be done, and for what remains undone the Universities are not responsible. They enjoy no princely revenues out of which they might, like the great English Universities, institute new chairs. They are deeply dependent on the munificence of private benefactors for each advance made in the direction of technical teaching. In the special departments with which I am connected, I may mention that I should like to see some new chairs founded, such as a chair of architecture and a chair of applied chemistry, and I strongly hope that the teaching of mechanical drawing in our University may soon be set on a more satisfactory footing than at present. These are branches in which decided advances are required, if our school is to be the first technical school in Edinburgh, and if our Universities are to be, as I hope they will be, the places where the highest kind of technical education is to be given. I will not enter into any condemnation of the Government for their backwardness in supporting and fostering scientific education, although it certainly is trying, when one knows the object is good, and that the money taken from the ratepayers would be repaid a hundredfold, to find that it is impossible to convince the Government departments of the utility of this expenditure. I firmly believe that the necessary funds will not be long wanting for the purposes to which I have referred, if the public are convinced of the utility of the objects proposed; and the Society of Arts is a body well able to instruct public opinion, and to give the most powerful and intelligent support to the cause of technical education in our Universities.

Mr GEORGE HARRISON proposed "The Museum of Science and Art," to which Professor ARCHER responded.

The last toast was "The Chair," proposed by Bailie COUSIN, and for which the CHAIRMAN returned thanks.

This concluded the evening's proceedings, which were of a most sociable and enjoyable nature throughout.

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APPENDIX (A.)

Proceedings of the Royal Scottish Society of Arts, Session 1868–69.

The Annual General Meeting of the Royal Scottish Society of Arts was held in their Hall, 117 George Street, on Monday, 9th November 1868—George Robertson, M. Inst. C.E., F.R.S.E., President, in the Chair.

1. The President gave an Address, for which, on the motion of Mr Charles Cowan, seconded by Mr David Rhind, thanks were awarded; and on the suggestion of Dr Stevenson Macadam, it was ordered to be printed in the Transactions of the Society. (See Paper, printed in the Transactions, Vol. VII. p. 576.)

2. The Report of the Prize Committee, awarding the Prizes for Session 1867–68, was read, and the Prizes were delivered by the President to the successful candidates. (See Appendix C.)

The Drawings of Inventions, for which the Prizes had been awarded, were exhibited.

The following Donations were laid on the table, and thanks voted to the respective Donors:—

1. Report of the British Association for the advancement of Science, Dundee, 1867. Presented by the Association.
2. Proceedings of the Royal Society, London. Nos. 103, 104. Presented by the Society.
3. The Practical Mechanic's Journal. Parts 41–44. Presented by the Proprietors.
4. The Journal of the Institute of Actuaries. Nos. 72, 73. Presented by the Institute.
5. The Journal of the Society of Arts, London. Nos. 816–832. Presented by the Society.
6. The Artizan. Vol. II. Nos. 8, 9, 10. Presented by the Proprietor.

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7. "Engineering." Vol. VI. Nos. 132-148. Presented by the Proprietors.

8. The Engineer. Vol. XXVI. No. 653. Presented by the Proprietors.

9. Proceedings of the Institute of Mechanical Engineers, Paris Meeting. Part 3. Presented by the Institute.

10. Proceedings of the Royal Institution of Great Britain. Vol. V. Parts 3 and 4. Presented by the Institution.

11. On the Present State of some branches of Iron Metallurgy. By St John Vincent Day, C.E.

12. On Certain Theories concerning the Great Pyramids of Jeeseh. By St John Vincent Day. Presented by Mr Day.

13. History and Description of the New Painted Window in the Parliament House. Presented by Mr Heath Wilson.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and approved.

II. Thomas Rowan, North Woodside House, was elected an Ordinary Fellow.

III. In terms of Law XV., the Society elected its Office-Bearers for Session 1868–69, viz.:—

DAVID STEVENSON, C.E., F.R.S.E., *President.*

Dr STRETHILL WRIGHT, M.D., M.R.C.P.E., 55 Northumberland Street,
JOHN GILLESPIE, W.S., 53 Northumberland St., } *Vice-Presidents.*

EDWARD SANG, F.R.S.E., 2 George Street, *Secretary.*

JOHN SCOTT MONCRIEFF, C.A., Chambers, 2 Frederick Street, *Treasurer.*

STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., &c., Surgeon's Hall, Nicolson Street, *Editor of Transactions.*

ALEXANDER JAMIESON, 71 Adam Square, *Curator of Museum.*

ALEXANDER KIRKWOOD, 9 St James' Square, *Medallist.*

THOMAS BELL, 117 George Street, *Officer and Collector.*

Ordinary Councillors.

FREDERICK HALLARD, F.R.S.E., Advocate, 7 Whitehouse Terrace.

JOHN LESSELS, Architect, 21 Heriot Row.

EDWARD ELMSLIE SANG, C.E., 2 George Street.

JOHN MACNAIR, 33 Moray Place.

ALLAN D. STEWART, C.E., 12 Castle Street.

WILLIAM FIRTH, Secretary, North British Rubber Company, Rose Villa, Viewforth.

JAMES GOWANS, Rockville, Napier Park.

ALEXANDER FRASER, Old Fish-market Close.

JOHN KIPPEN WATSON, Manager, Edinburgh Gas Company, 25 Waterloo Place.

ROBERT H. BOW, C.E., 7 S. Gray St.

JOHN PATERSON, C.E., 5 St Andrew Square.

ADAM MOSSMAN, Jeweller, 3 Princes Street.

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IV. A List of the Office-Bearers, and an Alphabetical List of the Fellows, as at 1st November 1867, had been previously sent to the Fellows.

V. A Copy of the Report of the Prize Committee for Session 1867–68, had also been sent.

Second Meeting—23*d November* 1868.—David Stevenson, C.E. F.R.S.E., President, in the Chair.

The President shortly thanked the Society for the honour they had conferred on him.

The following Communications were made:—

1. Description, with Drawings and Model of a Self-acting Apparatus for Tipping Coal Waggons. By George Romanes, C.E. The paper was referred to a Committee.

2. Description of a New Method for Producing Intense Light with Coal Gas. By James Allison Hogg, junr.

On account of some derangement in the apparatus, the discussion was delayed.

3. Part 5 of Vol. VII. of the Transactions was laid on the table.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Proceedings of the Royal Society, London. Vol. XVII. No. 105. Presented by the Society.

2. Journal of the Society of Arts, London. Nos. 833, 834. Presented by the Society.

3. "Engineering." Vol. VI. No. 149. Presented by the Proprietor.

4. The Artizan. Vol. II. No. 11. Presented by the Proprietor.

5. Scientific Opinion. Vol. I. No. 2. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and approved of.

II. The following Gentlemen were elected Ordinary Fellows:—

1. George Romanes, C.E., 19 Mayfield Terrace.
2. William Bowman M'Leod, dentist, 43 George Square.

Third Meeting—14*th December* 1868.—Dr Strethill Wright, Vice-President, in the Chair.

The following Communications were made:—

1. Experimental Illustration of a New Method for Producing Intense Light with Coal Gas. By James Allison Hogg, junr., gas engineer.

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The communication was remitted to a Committee.

2. Notice of some Improvements in the Construction of Theodolites. By Edward Elmslie Sang, civil and mechanical engineer. (See Paper printed in the Transactions, page 42.)

Specimens of the improved instruments were exhibited, and the communication was remitted to a Committee.

3. On Nitrous Oxide as an Anæsthetic. By William Bowman M'Leod, dentist.

Mr M'Leod showed the effect of the gas on some animals and on himself. Thanks were awarded for the interesting communication.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Proceedings of the Literary and Philosophical Society of Liverpool. Nos. 20 and 21. Presented by the Society.
2. Proceedings of the Institution of Mechanical Engineers for October. 1867. Presented by the Institution.
3. Journal of the Society of Arts, London. Nos. 835–837. Presented by the Society.
4. "Engineering." Vol. VI. Nos. 150–153. Presented by the Proprietors.
5. The Artizan. Vol. II. No. 12. Presented by the Proprietor.
6. Practical Mechanic's Journal. Part 45. Presented by the Proprietors.
7. Scientific Opinion. Nos. 3, 4. Presented by the Proprietors.
8. On the Estimation of Potassium. By James Chalmers, Chemist. and Robert R. Tatlock, Analytical Chemist, Glasgow. Presented by th Authors.
9. New Zealand Exhibition, 1865. Reports and Awards of the Jurors, with Essays on the Natural History of New Zealand. Presented by J. M. Balfour, Government Marine Engineer, Wellington.
10. President's Annual Address to the Actuarial Society of Edinburgh. Presented by the Society.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed

II. The following Gentlemen were elected Ordinary Fellows:—

1. James Mackenzie, chemist, 49 George IV. Bridge.
2. Fleeming Jenkin, Professor of Civil Engineering, 5 Fettes Row.

III. In terms of Law XX., the Society appointed a Committee to audit the Treasurer's books.

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Fourth Meeting—11*th January* 1869.—David Stevenson, C.E., President, in the Chair.

The President introduced Professor Jenkin, who, at the request of the Council, had agreed to give an address on Technical Education. (See Address, printed in the Transactions, p. 1.)

After Professor Jenkin's Address, Mr Leslie moved that the thanks of the Society be accorded to the Professor, and that the Address be printed in the Society's Transactions, which motion was seconded by Mr R. W. Thomson, and agreed to.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Proceedings of the Philosophical Society of Glasgow. Presented by the Society.
2. Transactions of the Institute of Engineers in Scotland. Vol. II. Presented by the Institute.
3. Journal of the Society of Arts. Nos. 838–841. Presented by the Society.
4. "Engineering." Nos. 154–157. Presented by the Proprietors.
5. Proceeding of the Institute of Mechanical Engineers for June 1868. Presented by the Institute.
6. Transactions of the Botanical Society. Vol. IX. Part 2. Presented by the Society.
7. Report on Machines and Mechanical Apparatus, by Robert Mallet. Presented by Mr Mallet.
8. Practical Mechanic's Journal. Part 46. Presented by the Proprietors.
9. The Artizan. Vol. III. No. 1. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentlemen were admitted Ordinary Fellows:—

1. Thomas Claxton Fidler, C.E., 9 Victoria Chambers, Westminster.
2. David Brodie, M.D., Columbia Lodge, Liberton.
3. David Sang, 9 Brandon Street.
4. Thomas Rowatt, Balmaghie, Palmerston Road.
5. Robert Gall, Jun., 20 Buchanan Street, Glasgow.
6. David Maclaren, 34 Buckingham Terrace.

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Fifth Meeting—25th January 1869.—John Gillespie, W.S., Vice-President, in the Chair.

1. The Report of the Committee on Mr Hogg's method of producing an intense light by coal gas was read and approved of; also, in expectation of farther experiments, the Committee was continued.

2. On a Few Useful Things Neglected. By James Elliot, formerly Professor of Mathematics in Queen's College, Liverpool. In this communication certain improvements are recommended in the construction of a pair of tongs, of latches of gates, and snecks of common doors, of ventilators, and of windows—not as improvements altogether unknown, but rather neglected. In regard to the first-mentioned article, the author recommends the points of the tongs to be roughened and to converge, and the hinge to be made concentric with the round plate which guards it. He next proposes that the oblique face of the staple, by which the latch of a gate is raised, should be concave, and not, as it is usually made, convex, and that the same change of form should be made on the slanting face of a common door-sneck. As to ventilators, he would construct the external orifice, for the admission of fresh air, in such a manner as to be self-adjusting, so as not to admit more air when a strong wind is blowing against it than when there is no wind at all,—a purpose which may easily be effected by means of a very simple valve. The subject next taken up refers to those unpleasant draughts which are so often felt in large rooms without any admission of currents of fresh air to cause them, arising from a portion of the interior atmosphere being reduced in temperature by cold walls and windows, and then descending, as a shower, on the heads of those below. To prevent the currents from the walls, all that is necessary is evidently to warm the room for a sufficient time before it is used; but, to prevent those from the windows, double glass is recommended as a perfect remedy, especially useful when the window is peculiarly exposed to cold winds. Double glass is also proposed for the roofs of hot-houses and conservatories, its use rendering artificial heat almost unnecessary.

Professor Elliot then goes on to the most important of his proposals, viz., a useful and very attainable resource for the rescue of sailors and others from ships driven on a lee-shore in a storm. Sometimes, he says, this disaster occurs where no attempt at rescue can be made from the shore, or, where that might be done, no life-boat or rocket-apparatus is within reach. On other occasions much valuable time is lost in getting out and manning a life-boat, or in fetching rockets from a distance. Instead of these, sometimes dangerous, sometimes impossible, always dilatory and often unsuccessful attempts, he recommends that every vessel should carry half a dozen strong canvas kites, of different sizes, and provided with cords of different strengths. Then, when necessity arose, either a small kite could be sent up carrying a common string to the shore, or a large one with a light rope, according to circumstances. The light string could be brought to the ground by a common *messenger*, as it is called, and could then be used for drawing a rope to the shore; or when, in the absence of assistance on the land, the large kite and rope are used, the messenger employed

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might carry a small anchor capable of attaching itself to objects on the shore. In either way a communication would be effected with the land without difficulty, and many lives, otherwise forfeited, might be saved. The author then points out that it is very seldom of any use to attempt to send a kite outward from the shore, and also that a kite may be so constructed that, by a slight change of adjustment, it may be made to fly either directly with the wind, or a point or two towards either side. Thanks were awarded to Professor Elliot.

3. Description of Captain Moncrieff's Protected Barbette System; illustrated by a Model. By Robert W. Thomson, C.E. Thanks were awarded to Mr Thomson.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 842, 843. Presented by the Society.
2. "Engineering." Nos. 158, 159. Presented by the Proprietors.
3. Scientific Opinion. Nos. 10, 11. Presented by the Proprietors.
4. Canadian Journal of Science, Literature, and History. Vol. XII. No. 1. Presented by the Proprietors.
5. Proceedings of the Institute of Mechanical Engineers. April 1868. Presented by the Institute.
6. Proceedings of the Royal Society. No. 106. Presented by the Society.
7. Mechanics' Magazine. No. 2309. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

Sixth Meeting—8th February 1869.—David Stevenson, C.E., President, in the Chair.

The following Communications were made:—

1. The Report of Committee on Mr Romanes' Self-Acting Apparatus for Tipping Coal Waggons, was read and approved of.
2. The Report of Committee on Mr Elmslie Sang's Improvements in Theodolites was read, and after some discussion was recommitted.
3. Description of a Self-Acting Railway Signal Lamp. By Andrew Carrick, accountant, Glasgow. The communication was remitted to a Committee.
4. On Light Railways. By W. J. Cockburn Muir, C.E. (See Paper printed in the Transactions, p. 44.) On account of the lateness of the hour, the accompanying relative note on the Question of Ruling Gradients by Mr Fidler, and also the discussion, were postponed.

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The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 844, 845. Presented by the Society.
2. "Engineering." Nos. 160, 161. Presented by the Proprietors.
3. Scientific Opinion. Nos. 12, 13. Presented by the Proprietors.
4. Proceedings of the Royal Society. No. 107. Presented by the Society.
5. Journal of the Institute of Actuaries. Vol. XIV. Part 6. Presented by the Institute.
6. Construction of Railway Carriages. By B. F. Fairlie, C.E.
7. Opinions of the Press on the Fairlie Engine. Presented by W. J. Cockburn Muir, C.E.
8. Address to the Students of the School of Design. By W. T. Thomson, F.R.S.E. Presented by Mr Thomson.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentlemen were admitted as Ordinary Fellows:—

1. Peter Shaw, contractor, 53 Lothian Road.
2. James Lawson Stewart, architect, Carluke.
3. Robert Burn, engineer, 24 Ann Street.

III. A proposal made by the Council to discontinue the Museum, was considered and agreed to.

IV. An Excerpt Minute of the Institute of Engineers in Scotland, reciprocating the admission of Members, was read and received with thanks.

Seventh Meeting—22*d February* 1869.—Dr Strethill Wright, Vice-President, in the Chair.

The following Communications were made:—

1. Continuation of Mr Cockburn Muir's paper on Light Railways, being the relative note on the Question of Ruling Gradients. By T. Claxton Fidler, C.E. (See Paper printed in the Transactions, p. 62.)

Considerable discussion took place on the many subjects referred to in these interesting papers.

2. Mr Hart exhibited in action a system of Electric Bells and Fire-alarums, and received a vote of thanks.
3. Suggestion of an improvement in the Selenograph. By the Secretary.

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The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 846, 847. Presented by the Society.
2. "Engineering." Nos. 162, 163. Presented by the Proprietors.
3. Scientific Opinion. Nos. 14, 15. Presented by the Proprietors.
4. Practical Mechanic's Journal. Part 47. Presented by the Proprietors.
5. The Artizan. Vol. III. No. 2. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. Mr Ellis Frederick Dudgeon was admitted an Ordinary Fellow.

Eighth Meeting—8th March 1869.—David Stevenson, C.E., President, in the Chair.

The following Communications were made:—

1. Notice of Two Experiments on the Legibility of Alphabets for the Blind, by the Rev. William Taylor, F.R.S., Worcester; together with a letter from the Rev. R. H. Blair, Principal of the College for Blind Youths of Rank, Worcester. Thanks were accorded to Mr Taylor and to Mr Blair.
2. Reflections on the Water Distribution within the City of Edinburgh. By Edward Sang, F.R.S.E. (See Paper printed in the Transactions, p. 64.)

After a lengthened discussion, the Society resolved, on the motion of Mr R. W. Thomson, seconded by Mr G. Cunningham, to hold a special meeting for the consideration of the general question of water-supply to the city.

PRIVATE BUSINESS.

I. The Minutes of the previous Meeting were read and confirmed.

II. The Report of the Auditing Committee was read; and

III. The President granted discharge to the Treasurer in terms thereof.

Special Meeting—11th March 1869 (To take into consideration the general question of Water-Supply to the City).—David Stevenson, C.E., President, in the Chair.

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The President, after a few introductory remarks, called on Mr Thomson to open the discussion. Mr Thomson then gave a general description of the present supply, and of the means of distributing it, and moved a resolution to the effect that the St Mary's Loch Scheme has been entered into before sufficient investigation has been made as to our present supply and wants. After a lengthened discussion, the resolution was put to the meeting and agreed to unanimously. (See Transactions, p. 72.)

Ninth Meeting—22*d March* 1869.—David Stevenson, C.E., President, in the Chair.

The following Communications were made:—

1. Improvement in the application of the Lime-Ball Light to the Illumination of Lanterns. By Robert H. Bow, C.E. Remitted to a Committee.
2. On the Cromoskiastereoscope, an instrument for the production of harmoniously coloured forms, with a Demonstration on the Structure of Solar Light. By Thomas Strethill Wright, M.D. Remitted to a Committee.
3. Report of Committee on Mr Elmslie Sang's Improvements on Theodolites was read and approved of.

The following Donations were laid on the table, and hanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 850, 851. Presented by the Society.
2. "Engineering." Nos. 166, 167. Presented by the Proprietors.
3. Proceedings of the Royal Physical Society of Edinburgh, 1864-65. Presented by the Society.

PRIVATE BUSINESS.

I. The Minutes of the Meeting on 8th March, and also those of the Special Meeting, were read and confirmed.

II. Mr R. H. Bow's Paper on Photometry, which had not been reported on during the previous Session, was remitted to a new Committee.

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Tenth Meeting—12*th April* 1869.—David Stevenson, C.E., President, in the Chair.

The following Communications were made:—

1. Statements on the Machinery used for Cleaning and Packing the East India Cotton, and on the Application of the Seeds for Feeding Cattle. By Robert Burn, engineer.

A cotton gin was exhibited in action; and thanks were awarded to Mr Burn.

2. Professor Jenkin's Paper on Braced Arches was delayed on account of indisposition.

3. Description of an Improved Variation Instrument, for observing directly the Variation of the Magnetic Needle. By Edward Elmslie Sang, C.E.

The instrument was exhibited, and the communication was remitted to a Committee. (See Paper printed in the Transactions, page 99.)

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 852–854. Presented by the Society.
2. "Engineering." Nos. 168–170. Presented by the Proprietors.
3. Scientific Opinion. Vol. I. Part 5. Presented by the Proprietors.
4. Practical Mechanic's Journal. Part 49. Presented by the Proprietors.
5. The Artizan. Vol. III. No. 4. Presented by the Proprietors.
6. Transactions of the Institute of Engineers in Scotland, 1868–69. Presented by the Institute.
7. Proceedings of the Royal Society. No. 109. Presented by the Society.
8. Transactions of the Royal Society of Edinburgh. Vol. XXV. Part 1; and
9. Proceedings of the Royal Society of Edinburgh, 1867–68. Presented by the Society.
10. Specifications of Patents. 40 vols. Presented by the Commissioners of Patents.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

Eleventh Meeting—26*th April* 1869.—Dr Strethill Wright, Vice-President, in the chair.

The following Communications were made:—

1. Description of an Apparatus for regulating the Supply of Water at different Levels. By A. M. Peters, plumber.

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The Author said—On being asked by your Secretary to give a further explanation of a drawing of a large iron tank exhibited by me at a former meeting of this Society, I did not hesitate to comply with his request, and now bring before you two drawings, and a working model, to assist me in that explanation. I do not pretend to touch on any theoretical points in thi explanation; but to set forth facts which have forced themselves upon my attention in the course of my experience of more than thirty years as a mechanic. The apparatus is capable of universal adaptation, but on the present occasion I limit myself to a description of its powers as applied to the distribution of water in Edinburgh.

Every citizen knows that Edinburgh is a place of hills and valleys—that very few of its streets stand upon the same level. And not only is the difference great between certain localities, but in not a few cases the gradients are very rapid—as between the Castle Hill and the foot of Canongate; the High Street and the Cowgate; George Street and Henderson Row, &c. &c. Now, it is evident that the supply of water to such a city is attended with special difficulties, if it be thought necessary to keep the pipes full in all the districts at one and the same time. For in order to do this the mains must be constantly full, and if so, the strain upon all the pipes in the lowest localities, on account of the declivities, must be very great. In proof that by the existing system of distribution this is found to be the case, I have only to remind you that it is found necessary to reduce and modify that strain at present by various expedients, as was stated by Mr Ramsay and Mr Hawksley in their evidence before the Select Committee on the Water Bill last Friday, and to mention further, what every working plumber knows, that it is still more thoroughly relieved by extensive leakage effected by the water itself.

This inequality of surface all over the town I consider to be an insuperable obstacle to the introduction of water into the houses of Edinburgh on the high-pressure principle from the mains, as is done in Glasgow, and necessitates its collection in private cisterns; but if these are to be kept properly supplied, it is necessary that the main pipes should be full nearly all the time, and in order to this, without their being strained or broken, I maintain that an equipoise is wanted to the great weight of water accumulating over our collecting area, whether on the Pentland or the Peeblesshire hills, or both. In fact, the demand for this equipoise increases as the quantity of water brought into the city is increased, as will be manifest immediately.

Let us suppose, for illustration of my meaning, that Edinburgh and its neighbourhood is fully supplied with water for all its requirements, if we take into account what is collected during the whole twenty-four hours. In that case, during the twelve or sixteen hours of a working day, fresh supply is constantly coming in from the reservoirs, nearly equal to what is used for manufacturing and domestic purposes. Then succeed the twelve hours during which the draught for manufacture stops, including the six or eight hours during which the draught for domestic use is *nil*, or nearly so. Now, if the supply brought in during the working portion of the day is nearly adequate to the demands then made upon it, the draught upon the reser-

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voirs is soon made up at night, and there is no relief given to the mains in resisting the weight of the accumulations taking place at the reservoirs situated at our collecting area. The consequence is, that when the mains are filled, the water is dammed back, causing immense pressure on the pipes in all the lower localities of the city, and in addition, causing the surplus which may be collecting on the hills to run to waste by the water overflowing the reservoirs during night, and running by natural channels to the sea. Nor does the loss stop here; the inhabitants lose the advantage of *having these waters collected at the opposite end of their system of distribution*, to form a compensating balance *which would ensure them a full supply all over the city, without undue strain upon the mains during the working hours of the next day.*

My plan for effecting this change in the mode of distributing the water through the city, which would greatly increase the value of our present collecting areas, and which, I maintain, would be indispensable to prevent bursting of the mains in lower localities were an "inexhaustible supply" introduced from anywhere else, is simply this:—Erect large tanks similar to drawing No. 1 in various parts of the city and suburbs, at an altitude of not less than 150 feet, each capable of containing about one million of gallons. The size of each tank would require to be about 100 feet square by 16 feet deep, and to be fitted up at the extreme ends of the main pipes. Say one at each of the following places:—Newington, West Coates, Granton, Leith, and Portobello. These tanks, as you will see from the drawing, to be supplied from the main pipe from the street, the supply pipe to the tank being the same as the main in diameter. The slide-valve ball-cock on the top of the tank is for filling it when the pressure on the main is at the strongest. In the bottom of the tank, as you will see by the drawing, I propose to place an inverted valve, which would open when the water in the main becomes weak by overdrawing from the lower levels, at the same time keeping up a counteracting pressure against the main supply pipes.

Now, I must direct attention to my working model to illustrate the practical operation of all this. We shall suppose that it is the close of our working day, and that the supply in our tanks is nearly reduced by the necessities of the last twelve hours. There is a little water in the tanks, thus showing that the mains are full. One by one our manufactories drop work, and their private cisterns are replenished, consequently their drawings are thrown back upon the main pipes. Immediately you see a relief is afforded to the main by the inverted valve in my tank rising and allowing the water to flow in gently. By-and-by the city goes to sleep, and the draughts for domestic use are not made, and the cisterns in the houses get filled, and my tanks again relieve the main pipes by shutting their inverted valves, and taking in all that the main pipes and the reservoirs cannot contain, by the slide ball-cock at the top. Morning comes, and the draught upon the main pipes recommences, and the supply from our collecting area is barely sufficient to meet our requirements. Of its own accord the inverted valve opens to make compensation to the main thus: just like a living thing, instinctively availing itself of appropriate apparatus at once to convey itself to the place where it is needed.

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These tanks, were they erected as I propose, would confer the following advantages :—

1*st*, They would render it possible to introduce water sufficient to supply all the houses in all the localities at one and the same time, and effectually save any strain upon the mains.

2*d*, Give additional collecting power within the city, and prevent overflow during night at the reservoirs.

3*d*, Prove an equipoise to the present distribution by means of the existing main pipes, and ensure a ready supply for sudden emergencies.

The second drawing illustrates the above principles, as modified and adapted for use in a tenement. Description of this cistern is unnecessary, as it is every way the same as the large tank already described, with the exception that there is a valve situated as near the main supply pipe on the street as possible, to prevent the water returning to the main when the inverted valve in the bottom of the cistern is open for supplying the tenement with water, when water in the main pipes on the street becomes weak through its withdrawal at lower levels, or when the water is shut off for repairs on the main pipes, which sometimes happens.

The apparatus was exhibited in action.

2. On a Method of preventing the Waste of Water in the Cisterns of Flatted Houses. By G. H. Slight, engineer.

In a town like Edinburgh, where a large proportion of the houses are lofty and divided into flats, there is a necessity for having the water supply brought to each floor ; and the method usually adopted here, consisting of a separate cistern on each flat, as compared with the constant service system direct from the main, or that in which one cistern at the top of the house serves for all the flats, has at least one important advantage to recommend its continuance, viz., the delivery of water at a sufficient but moderate and equal pressure on each flat, instead of the frequently excessive and dangerous pressure of the direct system, and the varying pressures of the single cistern arrangement. There are, however, practical difficulties attending the ordinary arrangement of cisterns for each flat. One of these may, and no doubt does, cause a very great waste of water, that is, the necessity which exists of preventing the overflowing of each cistern by means of a waste pipe leading to a drain, as in many cases, probably a large majority, the ball-cock for supplying the cistern from the main continues to run, either from accident or design, after the cistern is full, with the result of a nearly constant waste, more or less, according to the repair or adjustment of the ball-cock. Another serious evil is the not uncommon one of the pipe from the main being made of such a small size as not to be sufficient to supply all the cisterns at once ; consequently, when a considerable supply is taken at the lower cistern, the pressure of the water in the ascending pipe may be so much diminished as altogether to prevent the water from rising to the higher cisterns.

The object of this communication is to suggest a method by which all the advantages of the separate cisterns may be retained, and the disadvantages alluded to prevented to a large extent.

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Instead of having a branch from the ascending pipe for each cistern, it is proposed to carry the pipe direct to the upper cistern in a tenement, and there deliver a supply sufficient for all the cisterns of the series; then, instead of having a waste pipe from each leading to a drain, the waste or rather overflow pipe would deliver the surplus water to the next cistern below; from that a second overflow pipe would lead to the third cistern, and so on, while from only the lowest cistern there would be a real waste pipe, and the possible loss through it substituted for the possible loss from as many waste pipes as there are cisterns in the series.

This method so far would require very little alteration on the present arrangement of cisterns beyond disconnecting the lower ones from the supply pipe, and diverting the overflows from connection with the soil pipes to the supply of the cisterns below, though probably an enlargement of the overflow pipes might be required, as they might have to pass more water than at present.

A most important part of the arrangement would be the regulating of the supply to the upper cistern. For this purpose the cock on the supply pipe would have to be put in communication with each cistern of the series, in order that, as soon as water was drawn from any cistern, the supply might be turned on at the upper one, and so make up the deficiency through the intervening cisterns. Fortunately the ordinary practice is to have the various cisterns of a tenement directly above each other, and a simple arrangement in such a case would be to have the cock at the top fitted with a loaded lever, which would of itself keep the supply always shut off; then from the opposite end of the lever a wire would pass down as far as the lowest cistern, and be connected by means of a few links of chain to a float in each cistern, so that, when the water fell below its proper level in any one of them, the weight of the float in that cistern would come on the wire and open the cock at the top until the proper level of water was again attained, when the rising of the float would remove its weight from the wire and allow the counterbalance at the cock to shut off the supply. Even where the cisterns were not directly over each other, the wire could be carried round angles by bell cranks as in ordinary bell hanging, but these might necessitate more heavily loaded levers on the cocks and stronger apparatus generally.

By such an arrangement as has been described, there might be a greater likelihood than there is at present of a steady supply on each flat, while the chances of loss by waste pipes would in all probability be largely diminished, to say nothing of the lessening of possible evil in the shape of bad smells, by reducing the number of communications with the soil pipe or drain.

3. On a Pressure-Regulator for obtaining a Uniform Distribution of Water. By George Romanes, C.E.

The main part of this apparatus consists of a chamber, from which the water flows through an orifice, the pressure in the chamber being kept uniform, so as to secure a uniform flow.

A constant pressure is maintained in the chamber by a loaded plunger acting directly on an equilibrium valve on the inlet pipe, which valve

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checks the flow into the chamber just sufficiently to make the pressure in it support the load on the plunger.

To alter the quantity discharged it is only necessary to screw in an orifice of a different size, and adjust the quantity discharged precisely by the load on the plunger.

If each house had command of only a certain definite quantity of water per day, the house cisterns would probably require to be a little larger than at present, but waste would be prevented, and the water could be distributed with perfect fairness, independently of varying levels and distances, from the distributing reservoir, provided the street mains were large enough. The proper calculation of the sizes of the mains would then become much more simple.

4. Apparatus proposed for regulating the Supply of Water to Dwelling-Houses and Factories. By Edward Sang, C.E.

The consideration of the state of our water supply has been forced upon the citizens of Edinburgh by the sudden announcement that steps were being taken to obtain the sanction of Parliament to a scheme for bringing water to us from St Mary's Loch. The question at once and inevitably arose, "Is there a necessity for going to this great distance and incurring this enormous expenditure?" The Water Company's periodical report to the Town Council indicated a daily supply of over thirty gallons to each individual, a quantity certainly sufficient for, if not greatly beyond, the average wants of the inhabitants; yet, at the same time, there are continual cries about the scarcity of water.

Under these circumstances, I ventured to submit to the Society of Arts a few reflections on the subject, and endeavoured to indicate the expediency of recurring, in some degree at least, to the natural arrangement in which the supply to each individual and the payment therefor are correlated. The Society took the matter up in earnest, and held a special meeting to consider it.

The discussion at that special meeting revealed, or rather attested, a most deplorable state of affairs. Our supply is upwards of thirty-five gallons a-head per day, yet we have no systematic arrangements for distributing that enormous quantity. One family has abundance and to waste; the next to it has none at all, and must beg and borrow. The whole distribution is wrong; it is conducted on a false principle. The tenant of the lower flat, or even of the cellar, has the power of drawing off as much water as he pleases, leaving his neighbours above destitute and helpless. The officers of the Water Company are appealed to; they declare themselves unable to interfere; their duty ceases at the junction of the supply pipe with the main; there is plenty of water in the main, that is all they have to look to; the internal arrangement is at fault. Of this no one who looks at it can have any doubt.

The proposition that each house, or at least each flat, should have a separate connection with the main, would greatly mitigate but would not cure this evil. With full pressure and the ball down, the rate of discharge is such that in a quarter of an hour the day's supply for an ordinary family will run out. In other words, each one has, if the pressure could be kept

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up, the power of drawing off say one hundred times his fair share of the water. Any one, then, guilty of the egregious folly of tying up the handle of a water-closet, or of leaving a tap open, is wasting the supply which belongs to many of his neighbours. The careful are left entirely at the mercy of the careless and of the stupid. The economy of a hundred careful families does not compensate for the waste caused by a single careless one.

It appears to me that the only cure for this evil is to regulate, according to some fixed principle, the quantity to be delivered daily to each house, and to make the Water Company, or Trust, answerable for that delivery.

This may be accomplished in two ways. One is to provide a cistern capable of holding a day's supply, and to see that it is filled each day. This, however, would require a great amount of supervision. The other is to arrange an outlet which may deliver continually water at the required rate, into a house cistern of a capacity sufficient to meet the inequalities of demand, say sufficient to contain a day's supply. In the case of those for whom the stated supply is insufficient, a more plentiful one may be accorded at an additional charge.

If the principle of this arrangement be once conceded, there will be no difficulty in finding mechanical arrangements for carrying it into practice. That which, after considering a variety of plans, I had come to regard as the most satisfactory, is to construct a small cistern divided into two by a plate. The water is allowed to flow from the main into one of the halves, which is furnished with a ball and waste-pipe as usual. Since only a small continual stream is wanted, the orifice may be made minute, and the whole apparatus insignificant in bulk. At a fixed depth below the water-level a hole is made in the partition, which again is filled by a screwed plug having a carefully gauged aperture through which the water may escape into the second compartment. The size of this aperture is arranged so as to give the required daily supply. It may be interesting to have the actual dimensions stated. Supposing the orifice to be at the depth of one foot, and to be one inch in diameter, the flow through it in twenty-four hours would be 17,500 gallons, being enough to supply a population of 500 persons with thirty-five gallons a head. Hence, supposing five persons to a family, it follows that an opening of one-tenth of an inch in diameter, placed one foot below the surface, is sufficient to supply a family. We may then easily perceive that an apparently very small leak is enough to cause a serious waste.

From the second compartment of this distributing cistern the water is led off to the house cistern, which is furnished with a ball-cock to shut off the discharge when the water is not in demand and the cistern full. By this arrangement the family cannot waste any more water than is permitted to flow through the regulation orifice, and any carelessness is at once punished by a want of water.

The regulating cistern, after having been tested carefully, will require to be covered in and sealed so as to prevent interference; and it then becomes binding on the Water Company to maintain the level in the first compartment. By letting in a piece of glass near the upper edge, the surface of the water may be shown.

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When it is wished to alter the rate of supply, the plug has only to be unscrewed and a new one of a different diameter inserted. Also, when several houses in the same tenement are to be supplied, as many compartments may be made round the sides of the first one, each having its own regulation aperture and discharge pipes, and thus the expense may be reduced.

The effect of the introduction of such a plan for distributing the water, would be to render the rate of discharge through the mains almost uniform, so that the same system of pipes would give a greater total discharge per day than in the case of intermittent demand. Each householder would feel satisfied that he receives the full quantity to which he is entitled, and habits of economy in the use of water would be cultivated; it is by no means true that the profuse use of water and cleanliness are inseparable companions.

After considerable discussion, these four communications were referred to a Committee.

5. The Report of Committee on Mr Carrick's Self-acting Signal Lamp was read and approved of.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 855, 856. Presented by the Society.

2. "Engineering." Nos. 171, 172. Presented by the Proprietors.

3. Transactions of the Institution of Mechanical Engineers, July 1868. Presented by the Institution.

4. Proceedings of the Royal Society. No. 110. Presented by the Society.

5. Transactions of the Institution of Engineers in Scotland, Session 1868–69. Presented by the Institution.

6. Four Photograms of a Clock, with illuminated dial and centre-seconds-hand, manufactured by James Ritchie & Son for the Bombay Harbour Board. Presented by Messrs Ritchie.

7. Select Writings of the late Charles Maclaren, Esq. Presented by the Editors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The printed Annual Abstract of the Revenue and Expenditure of the Society for Session 1867–68, and on the state of the funds, was laid on the table.

III. In terms of Law XX., the Treasurer laid on the table a list of those Ordinary Fellows who are in arrear of their annual contributions.

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Twelfth Meeting—12*th July* 1869.—John Gillespie, W.S., Vice-President, in the Chair.

The following Communications were made:—

1. Description of a new Cabinet Cooking Apparatus, being the first of three papers on social reform in Cooking, Heating, and Ventilation. By J. D. Morrison, dentist.

2. Report of Committee on Mr Bow's paper on Photometry was read and approved.

3. Report of Committee on Mr Morrison's Apparatus Couch was read and approved.

4. Report of Committee on Mr Bow's improvement in the Application of the Lime-Ball Light to Lanterns was read and approved.

5. The Convener of the Committee on Dr Wright's Chromoskiastereoscope reported that Dr Wright does not desire a report.

6. Report of Committee on Mr Elmslie Sang's new Variation Instrument was read and approved.

7. Report of Committee on Mr Romanes' Pressure Regulator, on Mr Peters' Apparatus for regulating the Supply of Water at different Levels, on Mr Slight's Method of preventing Waste of Water in the Cisterns of Flatted Houses, and on Mr Sang's Apparatus for regulating the Supply of Water to Dwelling-houses and Factories, was read and approved.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts. Nos. 857–867. Presented by the Society.

2. "Engineering." Nos. 173–183. Presented by the Proprietors.

3. Proceedings of the Institution of Mechanical Engineers for June and November 1868. Presented by the Institution.

4. Proceedings of the Royal Society. No. 111. Presented by the Society.

5. Journal of the Institute of Actuaries. No. 75. Presented by the Institute.

6. Scientific Opinion. Vol. I. Parts 6, 7. Presented by the Proprietors.

7. Annual Report of the Cornwall Polytechnic Society, 1868. Presented by the Society.

8. The Artizan. Vol. III. No. 6. Presented by the Proprietors.

9. The Canadian Journal. Vol. XII. No. 2. Presented by the Proprietors.

10. Paper on Light Railways, by Mr Cockburn Muir, C.E. Presented by Mr Muir.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

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II. The following Gentlemen were admitted Ordinary Fellows, viz.:—

1. Sir David Baxter, Bart.
2. George Cousin, architect, City Chambers.
3. Alexr. Maxwell Adam, M.D., Lanark.

III. The Society appointed a Committee to award the Prizes for Session 1868–69.

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APPENDIX (B.)

LIST OF PRIZE SUBJECTS FOR SESSION 1869–70.

THE ROYAL SCOTTISH SOCIETY OF ARTS proposes to award prizes of different values, of Thirty Sovereigns, and under, in Gold or Silver Medals, Silver Plate, or Money, for approved Communications, *whether previously published or patented, or not,* submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the *Mechanical* and *Chemical* Arts in general, and in their relation to the Fine Arts, and also to means by which the *Natural Productions* of the Country may be made more available. The Society suggests the following as a few of the many subjects that may be attended to, viz.:—

I. INVENTIONS, DISCOVERIES, or IMPROVEMENTS in the Useful Arts.

1. *Mechanical Arts.*

INVENTIONS or IMPROVEMENTS in applying the Motive Power of Men and Animals,—in Wind and Water Prime Movers,—in Steam and other Heat Engines, including Gas Engines,—in Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines,—in Cotton and other Textile Manufacturing Mills,—in Ship-building in Wood, Iron, and Steel,—in Lighthouses,—in Marine Propellers,—in Railways, Plant, and Signals,—in Electric Apparatus,—in Electro-Magnetic Motive Power,—in Electric and other Telegraphic Apparatus, Sub-Marine and Aërial,—in Photographic Apparatus,—in Fire-Proof Buildings,—in Water Supply,—in Paving,—Sewerage,—in Economical Appliances for increasing the Sanitary condition of Towns,—in Smoke Consumption and Extinguishing Fires,—in Gas-Works,—

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in Canals and Inland Navigation, including the application of Steam Power to Canal Traffic,—Canal Locks, Inclines, and Lifts,—Application of Hydraulic Power for Lifts for Domestic Use,—for Cranes,—Printing Presses,—Organ-Blowing, and other similar purposes, where small Propelling Power is required,—Labour-saving Machines for working in Wood,—in Tools, Implements, and Apparatus for the various Trades,—in Sewing Machines,—in Bricks, Encaustic Tiles, Cements and Mortars,—in Printing Machines, Cases, and Rollers,—in Stereotyping,—in Cranes,—in the Machinery for Collieries,—in preserving Timber and Metals in Marine Works,—in Optical Apparatus,—in Manufacture of Paper,—Experiments on the Effect of Low Temperatures on Metals.

2. *Chemical Arts.*

INVENTION or IMPROVEMENTS in new and useful applications of Gutta Percha and Vulcanised India Rubber, or similar Gums,—in the Economical Extraction of Chemical Principles or Useful Substances, as Paraffine, &c., from Coal,—Porcelain Clay from Granite or Felspar,—and Metals generally from their Ores and Oxides,—in Dyes,—in Paints,—in Paper,—in Glass, especially for Lenses,—in methods of rendering the Electric Light available in practice.

3. *Relative to the Fine Arts.*

INVENTIONS or IMPROVEMENTS in Photographic processes, in "Carbon" Printing, and in Methods of Printing Photographs from their Impressions on Steel or Copper Plates, or Lithographic Stones,—in Electrotype processes,—in Die-Sinking,—in methods of illustrating Books, to be printed with the letterpress,—in Paper-Hangings,—in Articles of Porcelain, Common Clay, or Metal,—in Glass-Staining,—in Engraving on Stone,—in Chromo-Lithography,—in "Nature" Printing.

4. *Natural Productions.*

DISCOVERY of Plumbago Mines,—Whetstones,—of Woods suitable for Engraving.

II. EXPERIMENTS applicable to the Useful Arts.

III. COMMUNICATIONS of Processes in the Useful Arts practised in this or other Countries, but not generally known.

IV. PRACTICAL DETAILS of Public or other Undertakings of National importance, already executed, but not previously published;—or valuable suggestions for originating such undertakings.

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The KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts, which shall be primarily submitted to the Society" during the Session.

The HEPBURN BIENNIAL PRIZE, value about £12.

(*If not awarded during Session* 1868–69.)

"For such Inventions or Communications submitted to the Society as shall be approved of by the Society, or by their Prize Committee."

The MAKDOUGALL-BRISBANE BIENNIAL PRIZE, value £10.

(*If not awarded during Session* 1868–69.)

"To the Authors or Inventors of Communications of Merit, which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction."

The REID and AULD PRIZES.

For the First, Second, and Third best Models of "Anything New in the Art of Clock or Watch Making,—by Journeymen or Master Watch and Clock Makers,"—if these should be considered worthy of Prizes, the Year's Interest of the Reid and Auld Bequest, being about SEVEN GUINEAS, divided among them in such proportions as the Prize Committee shall fix, according to merit. To such as deserve it, the Society may add to the amount of the Prize out of its general funds.

GENERAL OBSERVATIONS

AND DIRECTIONS FOR PREPARING AND LODGING COMMUNICATIONS

The descriptions of the various inventions, &c., must be *full* and *distinct;*—be legibly written on *Foolscap* paper, leaving margins at least one inch and a half broad, on *both sides of each page,* so as to allow of their being bound up in volumes; and, when necessary, be accompanied by *Specimens, Drawings, or Models.* All Drawings to be on *Imperial* Drawing-Paper, unless a larger sheet be requisite. The Drawings to be in *bold* lines, not less than a quarter of an inch broad, or *strongly coloured,* so as to be easily seen at about the distance of thirty feet when hung up in the Hall, and the Letters or Figures of Reference to be at least 1½ inch long. When necessary, smaller and more minutely detailed Drawings should

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accompany the larger ones, for the use of the Committees, having the same letters of reference. Short abstracts must accompany the papers.

The Society shall be at liberty to publish in their Transactions copies or abstracts of all papers submitted to them. All Models, Drawings, &c., for which Prizes are given, shall be held to be the property of the Society; but the Value of the Model, if retained, will be separately allowed for.

Communications, Models, &c., are to be addressed to the SECRETARY, 2 George Street, Edinburgh, Postage or Carriage paid; and should be lodged on *or before* 1*st January* 1870, in order to insure their being read and reported on during the Session (the ordinary Meetings of which commence in November 1869, and end in April 1870). Communications lodged after the 1st March may not be read or reported on till the following Session.

By order of the Society.

EDWARD SANG, *Secretary.*

EDINBURGH, 9*th April* 1869.

*** *Copies for distribution may be had from the Secretary.*

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APPENDIX (C.)

REPORT

OF

THE COMMITTEE

APPOINTED BY

THE ROYAL SCOTTISH SOCIETY OF ARTS

TO AWARD PRIZES FOR COMMUNICATIONS READ AND EXHIBITED DURING SESSION 1868-69.

Your COMMITTEE having met and carefully considered the various Communications laid before the Society, and reported on during the Session 1868–69, beg to report that they have awarded the following Prizes:—

1. To EDWARD ELMSLIE SANG, Civil and Mechanical Engineer, Edinburgh,—for his "Description of an Improved Variation Instrument,"—Description read and Instrument exhibited, 12th April 1869 (No. 4203).

The Society's Silver Medal and Plate, value Ten Sovereigns.

2. To ROBERT HENRY BOW, C.E., F.R.S.E.,—for his Paper on Photometry,—read and illustrated by examples, 27th March 1865 (No. 4120).

The Society's Silver Medal and Plate, value Five Sovereigns.

3. To W. J. COCKBURN MUIR, C.E., London,—for his Paper on Light Railways,—read 8th February 1869.

The Society's Honorary Silver Medal.

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4. To THOMAS CLAXTON FIDLER, C.E., London,—for his "Note on the Question of Ruling Gradients,"—read 22d February 1869.

The Society's Honorary Silver Medal.

Your Committee recommend that, while *Thanks* are justly due to all those gentlemen who have sent Communications, the *Special Thanks* of the Society be given to the following gentlemen:—

1. To FLEEMING JENKIN, F.R.SS.L. & E., Professor of Civil Engineering in the University of Edinburgh,—for his "Address on Technical Education,"—delivered, at the request of the Council, 11th January 1869.

2. To R. W. THOMSON, C.E., F.R.S.E,—for his "Description of Captain Moncrieff's Barbette System,"—read and illustrated by a model, 25th January 1869.

3. To THOMAS STRETHILL WRIGHT, M.D., M.R.C.P.E.,—for his "Description of the Chromoskiastereoscope, an instrument for the production of harmoniously coloured forms,"—read and illustrated by experiments, 22d March 1869.

4. To Messrs A. M. PETERS, Plumber, G. H. SLIGHT, Engineer, GEORGE ROMANES, C.E., and EDWARD SANG, C.E.,—for their respective Communications on the Regulation of Water Supply,—read 26th April 1869.

All which is humbly reported, in name and by order of the Committee, by

EDWARD SANG,
Sec., Convener ex officio.

SOCIETY'S HALL, 117 GEORGE STREET,
6th October 1869.

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APPENDIX (D.)

ROYAL SCOTTISH SOCIETY OF ARTS.

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1867–68.

I. REVENUE AND EXPENDITURE.

I. GENERAL FUNDS.

Revenue.				Expenditure.			
Arrears of Annual Contributions received	£17	18	0	Prizes awarded	£2	4	0
Annual Contributions for Session 1867–68 received	283	10	0	Printing and Advertising	48	13	5
Interest on Account with the Commercial Bank received	1	13	6	Expenses of the Society's Printed Transactions	58	0	0
Compositions in lieu of Annual Contributions received, £40, 9s. 6d., whereof 5 per cent. applicable to Revenue, as recommended by Committee on Accounts	2	0	6	Books for the Library	0	5	0
				Fees to Committees for Reports	6	0	0
				Repairs, Furnishings, &c., for the Hall	35	14	1½
				Salaries and Expenses of Collection	140	10	9
				Miscellaneous Payments	15	10	6
	£305	2	0				
Excess of Expenditure over Revenue	1	15	9½				
	£306	17	9½		£306	17	9½

II. KEITH BEQUEST.

REVENUE.

Dividends from Edinburgh Gas-Light Company's Stock	£15	0	0
Dividends from British Linen Company Bank Stock	13	0	0
Dividends from Royal Bank Stock	9	15	0
Interest on Loan towards purchase of Society's Hall	7	4	7
Interest on Sums in Bank	4	8	8
Amount,	£49	8	3

EXPENDITURE.

Prizes awarded	£40	0	0
Excess of Revenue,	9	8	3

III. REID AND AULD BEQUEST.

REVENUE.

Dividends from National Bank Stock	£12	0	0
Interest on Sums in Bank	3	7	2
AMOUNT,	£15	7	2

IV. BRISBANE BIENNIAL PRIZE FUND.

REVENUE.

Dividends from Government Stock	£5	2	6
Interest on Bank Account	0	2	7
AMOUNT,	£5	5	1

EXPENDITURE.

Prize awarded	£10	0	0
Excess of Expenditure,	£4	14	11

V. HEPBURN PRIZE FUND.

REVENUE.

Dividends from Caledonian Railway Company Stock	£7	5	2
Interest on Bank Account	0	1	3
	£7	6	5

EXPENDITURE.

Prize awarded	£10	0	0
Excess of Expenditure,	£2	13	7

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I. REVENUE AND EXPENDITURE—continued.

VI. BUILDING FUND.

REVENUE.

Rents drawn from Letting of Hall		£143 14 8

EXPENDITURE.

Payments on account of Hall, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, &c., and Hall Keeper's Salary	£97 16 1		
Interest at 4 per cent. on Loans towards purchase of premises (including Loan from Keith Fund)	£34 11 7		
Interest on Bank Account	0 10 10		
		35 2 5	
			132 18 6
Excess of Revenue over Expenditure,			£10 16 2

II. FUNDS OF THE SOCIETY.

As at 15th November 1868, *per Report of Committee on Books and Accounts.*

I. GENERAL FUND.

1. Price of Hall in George Street and Furnishings, exclusive of the additional Premises purchased at Whitsunday 1863, and stated under "Building Fund," below			£1820 3 11
2. Arrears of Annual Contributions			35 14 0
3. Balance in Bank			155 17 10
			£2011 15 9
Less—1. Balance due to Treasurer	£133 2 9		
2. Balance of Subscriptions for Expenses of Conference on Technical Education unexpended	8 15 2		
		141 17 11	
AMOUNT,			£1869 17 10

II. KEITH BEQUEST.

1. Six Shares of the Edinburgh Gas-Light Company, at £52, 10s.,	£315 0 0		
2. £100 Stock of the British Linen Company's Bank	258 0 0		
3. £250 Stock of the Royal Bank, at £175, 10s.	438 15 0		
	£1011 15 0		
Less—1. Balance due to the Commercial Bank,	£14 15 11		
2. Balance due to Treasurer	1 1 9		
		15 17 8	
AMOUNT,			995 17 4

III. REID AND AULD BEQUEST.

1. £100 National Bank Stock	£252 10 0		
2. Balance in Bank	141 9 5		
3. Balance due by the Treasurer	0 1 10		
AMOUNT,			394 1 3

IV. BRISBANE PRIZE FUND.

1. £175, 3 per cent. Consols, at 94¼	£164 18 9		
2. Balance in Bank	6 10 5		
AMOUNT,			171 9 2

V. HEPBURN PRIZE FUND.

1. £100 Stock of the Scottish Central Railway Company	£136 10 0		
2. One £10 Share, No. 2, 4½ per cent. Preference Stock of do.	9 12 0		
3. Balance in Bank	2 15 5		
AMOUNT,			148 17 5

VI. BUILDING FUND.

(For the purchase of premises adjoining and under Society's Hall.)

Price of Premises and Furnishings, &c.	£891 16 4		
Less—Loans repayable	700 0 0		
AMOUNT,			191 16 4
Total value of Property and Funds under charge of the Society as at 15th November 1868			£3771 19 4

JOHN SCOTT MONCRIEFF, *Treasurer.*

EDINBURGH, 14*th April* 1869.

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APPENDIX (E.)

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS,

AS AT 1st NOVEMBER 1869.

THE QUEEN, PATRONESS.

OFFICE-BEARERS FOR SESSION 1868–69.

President, ... DAVID STEVENSON, C.E., F.R.S.E.

Vice-Presidents, ... Dr STRETHILL WRIGHT, M.D., M.R.C.P.E., 55 Northumberland Street.
JOHN GILLESPIE, W.S., 53 Northumberland Street.

Secretary, ... EDWARD SANG, F.R.S.E., 2 George Street.

Treasurer, ... JOHN SCOTT MONCRIEFF, C.A., Chambers, 26 Frederick Street.

Editor of Transactions, ... STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., &c., Surgeons' Hall, Nicolson Street.

Curator of Museum, ... ALEXANDER JAMIESON, 71 Adam Square.

Medalist, ... ALEXANDER KIRKWOOD, 9 St James' Square.

Officer and Collector, ... THOS. BELL, 117 George Street.

Ordinary Councillors.

FREDERICK HALLARD, F.R.S.E., Advocate, 7 Whitehouse Terrace.

JOHN LESSELS, Architect, 21 Heriot Row.

EDWARD ELMSLIE SANG, C.E., 2 George Street.

JOHN MACNAIR, 33 Moray Place.

ALLAN D. STEWART, C.E., 12 Castle Street.

WILLIAM FIRTH, Secretary, North British Rubber Company, Rose Villa, Viewforth.

JAMES GOWANS, Rockville, Napier Park.

ALEXANDER FRASER, Old Fishmarket Close.

JOHN KIPPEN WATSON, F.R.S.E., Manager, Edinburgh Gas Company, 25 Waterloo Place.

ROBERT H. BOW, C.E., F.R.S.E., 7 South Gray Street.

JOHN PATERSON, C.E., 5 St Andrew Square.

ADAM MOSSMAN, Jeweller, 30 Princes Street.

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LIST OF THE ORDINARY FELLOWS,

AS AT 1st NOVEMBER 1869.

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1822.*ABERCORN, The Most Noble James, Marquis of, K.G., &c., Chesterfield House, London.
1869. Adam, Alexr. Maxwell, M.D., Lanark.
1850.*Adie, A. J., F.R.S.E., C.E., 5 St Andrew Square.
1860. Adie, Richard, optician, 50 Princes Street.
1863. Aitchieson, Thos. Stodart, 74 George Street.
1860. Aitchison, William John, 11 Buckingham Terrace.
1865. Aitken, Henry, manager, Darroch Coal and Iron Works, Falkirk.
1868. Aitken, William, accoucheur, Eastwood, Carnwath.
1860. Alder, Henry, gas-meter maker, 32 Grange Road.
1851.*Alexander, William, M.E., 23 India Street, Glasgow.
1841.*Anderson, Charles W., merchant, Ashton, Dalkeith.
1850.*Anderson, Thos., M.D., F.R.S.E., Professor of Chemistry, 15 Shuttle Street, Glasgow.
1863. Andrews, James, C.E., 84 George St.
1861. Archer, Thos. C., Director of the Museum of Science and Art.
1868. Archibald, John, M.D., Biggar.
1826.*Aytoun, Robert, W.S., 3 Fettes Row.

1867. Baillie, John M., C.A., 15 Northumberland Street.
1856. Bain, Wm., engineer, Lochrin.
1857. Balfour, James M., C.E., New Zealand.
1836.*Ballantyne, J., of Holylee, Innerleithen.
1869. Baxter, Sir David, Bart. of Kilmaron, 5 Moray Place.
1865. Beattie, Adam, builder, 3 Chalmers Street.
1861. Beith, Donald, W.S., 43 Castle Street.
1850.*Bell, Alexander Melville, teacher of elocution, 18 Harrington Square, London.
1859.*Bell, Andrew Beatson, advocate, Cuttlehill House, Inverkeithing.
1857. Bell, B., surgeon, 8 Shandwick Place.
1858. Bell, James, railway-engineer, Portobello.
1867. Bell, Robert, coal-merchant, Wishaw.
1861. Bell, William, stockbroker, 8 North St David Street.
1867. Bennet, James Henry, engineer, 7 Vanburgh Place, Leith.
1861. Bernard, James A., 4 Manor Place.
1847.*Bernard, Thomas, brewer, 71 North Back of Canongate.
1840.*Berwick, David, accountant, 1 Reid Terrace.
1861. Bethune, Norman, M.D., 5 Mansion House Road.
1859. Black, Adam, publisher, 38 Drummond Place.
1865. Black, Rev. Arch. Pollok, The Manse, Bow Road, London.
1868. Blair, Rev. Rob. Hugh, rector of St Michaels, Worcester.
1863.*Blanshard, George, wholesale druggist, 7 Carlton Terrace.
1849.*Bouch, Thomas, C.E., 78 George Street.
1853.*Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street.
1863. Bowie, Andrew F., 4 Pilrig Street.
1868. Boyd, James L., S.S.C., 1 Regent Ter.
1848.*Brebner, A., engineer, 84 George Street.
1866. Bremner, Bruce A., M.D., Streatham House, Canaan Lane.
1868. Brockley, Robert, M.A., Cauvin's Institution, Duddingston.
1869. Brodie, David, M.D., Columbia Lodge, Liberton.
1861. Brown, D. R., manufacturing chemist, 1 St John Street.
1864. Brown, Geo. Bruce, architect, 26 Elder Street.
1867. Brown, John, builder, Pitt Street, Bonnington.
1839.*Brown, Thos., architect, 19 St Andrew Square.
1861. Brown, William Henry, of Ashley, Ratho.
1868.*Bruce, C., banker, 2 Glenfinlas Street.
1850.*Bruce, George Cadell, C.E., 21 Castle Street.
1833.*Bryce, D., architect, 131 George Street,
1851.*Bryden, J., bell-hanger, 55 George St.
1857. Bryson, J. M., optician, 60 Princes Street.
1860. Bryson, Robt., watchmaker, 66 Princes Street.

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1822.*BUCCLEUCH and QUEENSBERRY, His Grace Walter, Duke of, K.G., A.M., F.R.SS. L. & E., Dalkeith Palace.
1865. Buchanan, Walter B. Macallum, 3 Westbourne Terrace, Hyde Park, London, W.
1835.*Burn, William, architect, 6 Stratton Street, Piccadilly, London.

1851. Cadell, Henry, M.E., Grange, Bo'ness.
1846.*Callender, John A., merchant, Leith.
1859.*Cameron, P., contractor, 25 George Square.
1834.*Campbell, Alex., brewer, 6 Charlotte Square.
1862. Carlisle, James, engineer, 5 Hope Park Crescent.
1865.*Carmichael, Peter, Den's Works, Dundee.
1858. Carphin, James R., C.A., 26 Northumberland Street.
1840.*Carstairs, Drysdale, merchant, Liverpool.
1864. Carter, Frederick Hayne, C.A., 8 Eton Terrace.
1867.*Cay, Wm. Dyce, C.E., 7 Blackford Road.
1864. Chalmers, T., Longcroft, Linlithgow.
1867. Chambers, The Right Hon. William, of Glenormiston, Lord Provost of the city of Edinburgh.
1860. Charnock, Richard Stephen, 8 Gray's Inn Square, London.
1857. Chaumont, F. D., M.D., 1st Battalion Rifle Brigade, 44 Castle Street.
1861. Chisholm, David, actuary, 64 Princes Street.
1856.*Chisholm, John Knox, dentist, 15 Duke Street.
1860. Christie, John, Arniston Colliery, Gorebridge.
1840.*Christie, Robert, late manager, Scottish Equitable Assurance Company, 5 Merchiston Avenue.
1866. Clapperton, W. R., merchant, 59 Princes Street.
1862. Copland, Harry Y. D., 27 Stafford St.
1847.*Cousin, David, city-architect, City Chambers.
1869. Cousin, George, architect, 5 Bruntsfield Terrace.
1836.*Cowan, Charles, paper-manufacturer, Valleyfield, Penicuik.
1864. Cox, John, glue manufacturer, Gorgie House, Murrayfield.
1859. Cox, Robert, W.S., 25 Rutland Street.
1863. Craig, David, paper-maker, Portobello.
1866.*Craig, James, distiller, 33 Manor Place.
1865.*Craig, Robert, paper-maker, Craigesk, Dalkeith.
1832.*Craig, Sir William Gibson, of Riccarton, Bart, F.R.S.E., Hermiston.
1860. Cuningham, Alex., secretary to the Commissioners for Northern Lights, 84 George Street.
1851.*Cunningham, George, C.E., 2 Ainslie Place.
1857. Cunningham, James, W.S., F.R.S.E., 50 Queen Street.
1863. Currie, Heriot, engineer, 4 Auburn Place, North Leith.
1867. Cusiter, G. F., gas-engineer, Dalkeith.

1866. Davidson, George W., M.D., 40 Lothian Street.
1868. Davidson, James, M.E., Newbattle.
1865. Davies, Arthur Ellson, 4 High School Yards.
1850. Davison, Samuel D., Hawthorn's Works, Leith.
1865. Day, St John Vincent, C.E., 166 Buchanan Street, Glasgow.
1867. Deans, Peter Dods, Mount Charles, Portobello.
1865. Deas, James, C.E., Glasgow.
1844.*Dickson, J. Jobson, C.A., 13 Clarendon Crescent.
1850. Dickson, John, junior, gunmaker, 63 Princes Street.
1866. Dods, G., assessor of railways, 5 Gayfield Square.
1860. Douglas, F. Brown, 21 Moray Place.
1859.*Dryborough, Rich., cooper, 4 Hermitage Place, Leith.
1869. Dudgeon, Ellis Frederick, 15 St Bernard's Crescent.
1866. Duncan, Thos., 16 Mansion House Road.
1866. Dunn, John H., writer, 3 Lord Russell Place.
1844.*Dunn, Thos., optician, 7 Buccleuch Pl.

1853. Elliot, Professor James, Laighwood, Dunkeld.
1839.*Ellis, T., upholsterer, 21 George IV. Bridge.
1864. Ellis, W. M., merchant, 8 Wellington Street, Portobello.
1857. Esson, Geo. A., Accountant in Bankruptcy, 10 Great King Street.

1850.*Falshaw, James, C.E., 26 Castle Street.
1864. Ferguson, John, engraver, North St Andrew Street.
1857. Ferguson, R. M., Ph.D., F.R.S.E., 12 Moray Place.
1850.*Ferguson, William Black, C.E., 129 Union Street, Aberdeen.
1869. Fidler, Thomas Claxton, C.E., 9 Victoria Chambers, London.
1864. Field, Thomas, slate-merchant, 27 Frederick Street.

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1860. Firth, William, secy., N. B. Rubber Co., Castle Mills.
1840.*Fleming, Alex., W.S., 20 Lynedoch Pl.
1861. Fleming, A. B., chemical manufacturer, 12 Eton Terrace.
1865. Flockhart, Wm., chemist, 52 North Bridge.
1866. Forbes, John, LL.D., house-governor, Donaldson's Hospital.
„ Forman, John, 51 Great King Street.
1840.*Forrester, John, W.S., 8 Drummond Place.
1850.*Fraser, Alex., printer, Old Fishmarket.
1847.*Fullarton, John A., publisher, 12 Claremont Street.

1869. Galt, Robert, jun., coal-master, 20 Buchanan Street, Glasgow.
1856.*Geddes, A. C., C.E., 1 Erskine Place.
1856.*Geddes, G. H., M.E., 3 W. Maitland St.
1842.*Gillespie, John, W.S., 53 Northumberland Street, *Vice-President*.
1854.*Girdwood, Robert, merchant, Tanfield.
1850.*Glennie, Geo., C.E., 43 Upper Thames Street, London.
1859. Gordon, Alexander, colliery manager, Thorniebank, Dalkeith.
1861. Gowans, Alex., architect, 3 Viewforth.
1850.*Gowans, James, builder, Rockville, Napier Road.
1865. Gray, Alex., ironmonger, 85 George St.
1832.*Gray, James, ironmonger, 39 Gt. King Street.
1861. Gray, Robert, gas-engineer, 15 Carnarvon Street, Glasgow.
1860. Gray, Rev. W. H., M.A., minister of Lady Yester's, 5 Regent Terrace.
1866. Greene, R. Massy, C.E., New Dock Works, Leith.
1850. Gregory, Thos. Currie, C.E., Glasgow.
1858. Greig, David, engineer, Greenhill Park.
1835.*Groat, A. G., of Newhall, 12 Hart Street.

1855. Hallard, Fredk., Sheriff-substitute of Edinburgh, County Buildings.
1833.*Hamilton, Alex., W.S., LL.B., F.R.S.E., 35 Queen Street.
1834.*Hamilton, Jn., W.S., 7 Great Stuart St.
1860. Hardie, Walter, printer, 2 William St.
1866. Harrison, G., merchant, 12 Blackford Road.
1855. Hart, Wm., phil.-instrument maker, 7 North College Street.
1840.*Harvey, Sir George, P.R.S.A., F.R.S.E., 21 Regent Terrace.
1853.*Hay, Geo. W., of Whiterigs, F.R.S.E., Sudbury, Derby.
1835.*Hay, James, F.R.S.E., merchant, Leith.
1867. Hay, William, architect, 7 Hill Street.
1863. Henderson, Robert, builder, 21 West Maitland Street.
1856. Henry, Alex., gunmaker, 12 South St Andrew Street.
1836.*Hepburn, J. Stewart, of Colquhalzie Auchterarder.
1839.*Hill, Laurence, jun., C.E., Inch Works Port-Glasgow.
1863. Hogue, D. W., M.D., dentist, 65 Queen Street.
1864.*Hood, Archibald, M.E., Whitehill Colliery, Lasswade.
1868. Horsburgh, John, photographer, 131 Princes Street.
1834.*Horsburgh, Robt., Southbank House, Penicuik.
1863. Hossack, B. H., teacher, 33 Charlotte Sq.
1838.*Hunter, Richard, H.E.I.C.S., 10 Ainslie Place.
1859. Hunter, Robert, advocate, Sheriff of Buteshire, 67 Northumberland St.
1864. Hunter, Thos. M., teacher of music, 53 George IV. Bridge.
1856. Hurst, Wm., engineer, 5 Gayfield Sq.

1857. Imlach, Francis B., F.R.C.S.E., 48 Queen Street.
1859. Ivory, Thomas, advocate, 23 Walker St.

1854. Jackson, Ed. James, B.A. Oxon., 6 Coates Crescent.
1850.*Jardine, Wm. Alex., C.E., 19 Queen St.
1848.*Jefferiss, Robert R., M.D., Dalkeith.
1869. Jenkin, Fleeming, F.R.SS. L. & E., Professor of Civil Engineering, 5 Fettes Row.
1858. Johnston, Adam, solicitor, 4 North St David Street.
1840.*Johnston, Alex. K., LL.D., F.R.S.E., geographer to the Queen, 4 St Andrew Square.
1867. Johnstone, James, of Larchhill, 9 Royal Terrace.
1850.*Johnstone, William, C.E., 14 Bridge Street, Glasgow.
1857. Johnston, William, mining-manager, Blair-Adam.
1850.*Jopp, Charles, C.E., 3 Royal Terrace.

1857. Kay, John Zuill, Phœnix Iron Works, Glasgow.
1839.*Kennedy, Wm., W.S., 59 Northumberland Street.
1867. Kennedy, W. Wemyss, machinist, 111 Princes Street.
1865. Kerr, John F., gas-engineer, Copiapo, Chili.
1836.*Kirkwood, Alex., *Medalist*, 9 St James' Square.
1857. Kirkwood, Wm. B., accountant, 7 St Andrew Square.

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1861. L'Amy, Sylvester.
1857. Landale, And., iron-master, Lochgelly.
1852.*Landale, David, M.E., 6 Forth Street.
18[illegible]8. Landale, James, M.E., 6 Forth Street.
[illegible]34.*Laurie, Wm. A., K.H.M.G., Gazette Office, 13 N. Bank Street.
1836.*Lawson, Charles, of Borthwick Hall, 35 George Square.
1858. Lawson, Charles, jun., seedsman, 34 George Square.
1859. Lawson, Geo. Stodart, 35 George Sq.
1836.*Lees, George, LL.D., St Andrews.
1850.*Lees, Henry, accountant, 6 York Place.
1856. Lees, Wm., A.M., Linkvale, Viewforth.
1866.*Leslie, Alexander, C.E., 2 Charlotte Square.
1850.*Leslie, James, C.E., 72 George Street.
1850.*Lessels, Jn., architect, 21 Heriot Row.
1863. Lockhart, James, engineer, 27 Elmbank Place, Glasgow.
1852. Lorimer, James, C.E., 99 George St.
1862. Lundy, J. J., Assembly Street, Leith.

1856.*Macadam, Stevenson, Ph.D., F.R.S.E., *Editor of Trans.*, Surgeons' Hall.
1839.*Macbrair, D. J., S.S.C., 12 Gt. King St.
1868. MacCallum, James, C.E., 35 Lorraine Place, Newcastle-on-Tyne.
1850.*Macdonald, D., cotton-spinner, Aberdeen.
1866. Macdougall, William, C.E., 17 Buckingham Terrace.
1868. Macfarlane, Walter, Saracen Foundry, Glasgow.
1852.*M'Farlane, Wardlaw, chemist, 4 Merchiston Avenue, Morningside.
1861. M'Glashan, Stewart, sculptor, Canonmills Bridge.
1850.*Mackay, John, pharmaceutical chemist, 121 George Street.
1861. Mackenzie, Charles, bookseller, The Avenue, Greenhill.
1838.*Mackenzie, James, W.S., 9 Doune Ter.
1867. M'Kenzie, James, manager, Scottish Vulcanite Co., Viewforth.
1869. Mackenzie, James, chemist, 49 George IV. Bridge.
1859. M'Kinlay, William, coalmaster, Bathgate.
1839.*Maclagan, Douglas, M.D., F.R.S.E., Prof. of Medical Jurisprudence, 28 Heriot Row.
1863.*Maclagan, Peter, of Pumpherston, M.P., Mid-Calder.
1867.*Maclagan, R. Craig, M.D., 5 Coates Crescent.
1869. Maclaren, David, 34 Buckingham Ter.
1866. M'Laren, Duncan, M.P., Newington House.
1858. M'Lean, Hector Frederick, W.S., 3 Hill Street.
1869. M'Leod, William Bowman, dentist, 43 George Square.
1861. M'Nab, John, Inglis Green, Slateford.
1861. Macnair, John, 33 Moray Place.
1867. Macnaughton, Alexander, S.S.C., 18 Young Street.
1863. Macnie, John, gas-engineer, Lecky Road, Londonderry.
1861. Macpherson, Chas., C.E., 10 Glengyle Terrace.
1850.*Marjoribanks, William, merchant, Warriston House.
1867. Marshall, David, engineer, Madeira Street, North Leith.
1843.*Marshall, G. H., jeweller, 3 Heriot Row.
1858. Marshall, Thomas R., goldsmith, 7 Castle Terrace.
1860. Marshall, William, engineer, Madeira Street, North Leith.
1867. Martin, William, glass-merchant, 55 Lothian Road.
1860. Matheson, Robert, architect, 25 Abercromby Place.
1867. Maule, Thos. H., LL.D., Eildon House, Melrose.
1850.*Mein, Archd., dentist, 94 George Street.
1861. Meldrum, Ed., of Dechmont, Bathgate.
1860. Melville, F. Suther, assistant-clerk of Session, 16 Broughton Place.
1850.*Melville, Jas. M., W.S., 110 George Street.
1863. Menzies, Duncan, architect, 13 Young Street.
1867. Menzies, John, C.E., 25 Pitt Street.
1865. Menzies, Wm. John, W.S., Canaan Cottage.
1866. Messer, Robert, C.E.
1862. Millar, David, builder, Mansfield Cottage, Bellevue.
1857.*Millar, John, merchant, 13 York Place.
1829.*Miller, Jn., of Leithen, C.E., F.R.S.E., M.P., 2 Melville Crescent.
1868. Miller, Richard R., Upper Hermitage.
1861. Millidge, J.J., goldsmith, 28 Princes Street.
1859.*Miln, James, of Muric.
1865. Milne, James, engineer, 16 Windsor Terrace, Glasgow.
1848.*Milne, John Kolbe, dressing-case maker, 126 Princes Street.
1859.*Milne, John, 44 Albany Street.
1850.*Moffatt, W. L., architect, 23 Minto Street.
1838.*Moncrieff, John Scott, C.A., *Treasurer*, 26 Frederick Street.
1865. Moore, Wm., M.E., 49 West George Street, Glasgow.
1863. More, Jas. L., writer, 25 Scotland Street.
1854. Morrison, Adam, S.S.C., 45 York Place.

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1858. Morrison, J. D., dentist, 27 Grange Road.
1838.*Morton, Hugh, engineer, Victoria Dock, Leith.
1855.*Mossman, Adam, jeweller, 30 Princes Street
1858. Mudie, D. C., Panmure Foundry, North Back of Canongate.
1857. Muir, John, brewer, 5 Pilrig Street.
,, Muir, R. G., brewer, 9 Bellevue Ter.
1866. Muir, W. J. Cockburn, C.E., 9 Victoria Chambers, Westminster, London.
1861. Muirhead, Andrew, painter, 22 Nelson Street.
1868. Murray, John, 48 Castle Street.

1838.*Nachot, W. H., Ph.D., teacher of German, 73 Queen Street.
1868. Nairn, Andrew, 21 Albany Street, Leith.
1860. Nelson, Thomas, publisher, Hope Park.
1858. Nicol, John, chemist, 4 Dundas St.

1850.*Ogilvie, A., merchant, Old Liston, Ratho.
1866. Oliver, John S., merchant, 8 Greenhill Park.
1860. Ower, C., engineer, Craigie Ter., Dundee.

1865. Park, Ebenezer, engineer, 18 Greenside Lane.
1863. Park, James Dove, engineer, 18 Greenside Lane.
1866. Parkes, S. H., 5 St Mary's Road, Birmingham.
1844.*Paterson, John, C.E., 27 Hope Terrace.
1846.*Paterson, W., Scot. Cent. Rail., Perth.
1859. Paterson, Wm., banker, 4 Regent Ter.
1868. Paton, Samuel, teacher, Lamington.
1864. Pattison, Walter G., merchant, Sea Cliff House, Trinity.
1840.*Pearson, Charles, C.A., 128 George St.
1861. Peebles, D. B., engineer, 91 West Gilmore Place.
1865.*Peters, A. M., plumber, 13 Dundas St.
1862. Pilkington, F. T., architect, 2 Hill St.
1861. Platt, Leon J., dentist, Stirling.
1859. Playfair, Lyon, C.B., F.R.S.E., M.P.
1868. Potts, R. Collins, 15 Henderson Place, Ferry Road.
1864. Proudfoot, David C., burgh surveyor, 10 Union Street, Leith.

1862. Rainie, Robert, C.A., 6 Clifton Ter.
1850.*Ramsay, Alex., manager, Edin. Water Co., 123 Princes Street.
1835.*Ranken, Francis, glass-merchant, 16 Picardy Place.
1842.*Rankine, W. J. Macquorn, F.R.SS. L. and E., Prof. of Civ. Eng., 59 St Vincent Street, Glasgow.
1857. Reid, A., optician, 31 Castle Street.
1860. Reid, John, engineer, Edin. and Leith Gas Co., 2 Queen's Place, Leith.
1848.*Reid, R. L., painter, 2 Blenheim Place.
1843.*Rhind, David, F.R.S.E., architect, 54 Great King Street.
1850.*Richardson, R., merchant, 16 Bruntsfield Place.
1865. Riddock, Jn., teacher, Neston, Cheshire.
1853. Ritchie, A., watchmaker, 29 Leith St.
1867. Ritchie, David, smith, 38 Candlemaker Row.
1865. Ritchie, Frederick James, clockmaker 25 Leith Street.
1862. Ritchie, James, wholesale stationer 140 High Street.
1866. Ritchie, Jas., watchmaker, 25 Leith St.
1834.*Ritchie, R., C.E., Assoc. Inst. C.E., 16 Hill Street.
1843.*Roberts, W.A., M.D., dentist & surgeon, 30 Queen Street.
1866. Robertson, Andrew, secretary, Scottish Provincial Assurance Company, 65 Princes Street.
1859. Robertson, G., M. Inst. C.E., F.R.S.E. 47 Albany Street.
1855. Robertson, J., druggist, 35 George Street.
1864. Robertson, William, engineer, 16 Madeira Street, Leith.
1857. ROLLO, Right Hon. Lord, Duncrub House, Bridge of Earn.
1868. Romanes, George, C.E., 12 Mayfield Loan.
1853.*Rose, J. T., shipbuilder, 3 Oxford Street.
1868. Rowan, Thomas, North Woodside House, Glasgow.
1869. Rowatt, Thomas, lamp-manufacturer, Palmerston Road.
1867. Rowbotham, Rev. Frederick, M.A., 3 Bellevue Place.
1838.*ROXBURGHE, His Grace James H. R., Duke of, K.T., Floors, Kelso.
1866. Russel, John, merchant, 4 Baxter's Pl
1835.*Russell, J. Scott, C.E., F.R.SS. L. & E. Sydenham, London.
1856. Russell, Norman Scott, C.E.

1864. Samuel, Peter, merchant, 15 Hanover Street.
1843.*Sanderson, J. H., lapidary, 92 Princes Street.
1867. Sanderson, William, rectifier, Quality Street, Leith.
1869.*Sang, David, 9 Brandon Street.
1828.*Sang, Edward, F.R.S.E., 2 George Street, *Secretary*.
1860. Sang, Edw. Elmslie, C.E., 2 George St.
1843.*Schenck, Frederick, lithographer, 8 South St Andrew Street.

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1850.*Scott, Arch., architect, 10 Teviot Row.
1866. Scott, Thomas, engineer, Inverkeithing.
1867. Scott, Wentworth Lascelles, analyst, Wolverhampton.
1850.*Scrymgeour, Henry, upholsterer, 73 George Street.
1851. Seton, Lt.-Col. R. S., Madras Artillery, 9 Windsor Street.
1864. Shand, George, chemist, Stirling.
1843.*Shanks, Thomas, engineer, Johnston, Renfrewshire.
1869. Shaw, Peter, contractor, 6 Cambridge Street.
1867. Shearer, Wm., philosophical instrument maker, 10 Rankeillor Street.
1862. Shedden, Thomas, M.A., Arrochar.
1866. Sim, Francis Ranken, glass-merchant, 96 Princes Street.
1863. Sim, William, Edinburgh Colour Works, Leith Walk.
1865. Simpson, George, Bonhar Colliery, Whitburn.
1846.*Simpson, Sir James Y., Bart., M.D., F.R.S.E., 52 Queen Street.
1864. Simpson, James, architect, Daisy Bank, Ferry Road.
1856. Slight, G. H., engineer, 34 Leith Walk.
1862. Sligo, A. V. S., 5 Drummond Place.
1854. Small, John, Librarian, University.
1857. Smith, Adam G., C.A., 5 Lennox Street.
1850.*Smith, A., C.E., 32 Dundas Street,
1839.*Smith, D., F.R.S.E., manager, North British and Mercantile Insurance Co., 64 Princes Street.
1865. Smith, David, contractor, 61 Brougham Street, Belfast.
1867. Smith, G. H., M.D., 80 Great King Street.
1864. Smith, John, C.E., 8 Buckingham Terrace.
1865. Smith, John D., carver and gilder, 21 Frederick Street.
1856. Smith, Robt. M., F.R.S.E., merchant, 4 Bellevue Crescent.
1859. Smith, William, lithographer, 43 Northumberland Street.
1855. Smyth, Chas. Piazzi, F.R.SS.L. & E., Astronomer-Royal for Scotland, 1 Hillside Crescent.
1867. Sorley, John, LL.D., Birkenhead Cottage, Birkenhead.
1865. Soutter, James, merchant, 102 Princes Street.
1859. Spence, W., Sec., B. L. Co. Bank, 36 St Andrew Square.
1840.*Sprot, T., W.S., 10 Drummond Place.
1850.*Stark, James, M.D., F.R.C.P., F.R.S.E., 21 Rutland Street.
1861. Steedman, John, manager, Charlestown Works, Dunfermline.
1835.*Steele, Pat. S., merchant, Eastbourne House, Portobello.
1867. Steuart, Charles, jun., W.S., 8 Doune Terrace.
1847.*Steuart, James, W.S., 8 Doune Ter.
1841.*Steuart, R., of Carfin.
1838.*Stevenson, David, C.E., F.R.S.E., 84 George Street, *President*.
1840.*Stevenson, P., philosophical-instrument maker, 61 Geo. IV. Bridge.
1847.*Stevenson, Thomas, C.E., F.R.S.E., 84 George Street.
1863. Stewart, A. Duncan, C.E., 12 Castle Street.
1869. Stewart, James Lawson, architect, Carluke.
1850.*Stewart, J. W., C.E., 13 Young St.
1865. Stewart, Neil, artist, 11 W. Richmond Street.
1864. Strong, Thomas, W.S., 45 Melville Street.
1857. Sturrock, John., jun., 3 Queen's Crescent, Newington.
1868. Sutter, Archibald, C.E., 3 Hill Street.
1846.*Swan, Prof. Wm., F.R.S.E., St Andrews.
1858. Swann, J. R., builder, 21 Leith Walk.
1866. Syme, F. D., 14 Great King Street.

1858. Taplin, T., M.D., U. S. Club, Queen Street.
1866. Tatlock, Robert R., analytical chemist, 151 George Street, Glasgow.
1862.*Tawse, John Wardrobe, W.S., 49 Queen Street.
1868. Templeton, J., manufacturer, Glasgow.
1851. Tennant, Charles, St Rollox, Glasgow.
,, Tennant, John, St Rollox, Glasgow.
1860. Thomson, Alex., teacher, 5-A George Sq.
,, *Thomson, C. W., C.A., 9 Blenheim Pl.
1863. Thomson, R. W., C.E., 3 Moray Pl.
1839.*Thomson, W. T., F.R.S.E., 3 George Street.
1830.*Tod, Henry, W.S., 39 York Place.
1858.*Tod, James, advocate, 56 Northumberland Street.
1861. Tod, James, engraver, 3 St James' Sq.
1856. Tod, John, engineer, 29 Leith Walk.
1846.*Trevelyan, Arthur, of Pencaitland, Tyneholm, Tranent.
1840.*Trevelyan, Sir Walter C., Bt., F.R.S.E., Wallington, Newcastle-on-Tyne.
1864. Trotter, Alexander, teacher, 59 George Street.
1840.*Turnbull, W., F.R.S.E., accountant, Royal Bank.
1822.*TWEEDDALE, The Most Noble George, Marquis of, K.T., F.R.S.E., Yester House, Gifford.

1860. Vallance, George, merchant, 1 Gayfield Square.

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1840.*Walker, William, surgeon and oculist, 47 Northumberland Street.
1859. Wallace, Alex., M.A., assist.-observer, Royal Observatory.
1856. Waterston, George, jun., stationer, 56 North Hanover Street.
1866.*Watherston, James, builder, 8 Charlotte Place.
„ *Watherston, William, builder, 8 Charlotte Place.
1840.*Watson, Henry George, C.A., 123 George Street.
1860. Watson, John Kippen, F.R.S.E., treas. and manager, Edin. Gas-Light Company, 25 Waterloo Place.
1850.*Webster, Andrew, S.S.C., 3 Forth St.
1865. Welsh, Richd., coppersmith, 4 Queen's Place.
1861. Whimster, T., gas-engineer, Perth.
1867. Whitehead, John, S.S.C., 15 St Andrew Square.
1846.*Whitelaw, James, watchmaker, 30 W. Register Street.
1867. Whytock, A., merchant, 9 George St.
1838.*Wilkie, John, of Foulden, Berwick-upon-Tweed.
1851. Willet, John, C.E., Aberdeen Railway.
1859. Williamson, Peter, assistant-observer, Royal Observatory.
1864. Wilson, Andrew, dentist, 21 Young St.
1867. Wilson, James T., manufacturing-chemist, Restalrig House.
1858. Wilson, John, coalmaster, South Bantaskine, Falkirk.
1859. Wilson, John, F.R.S.E., Professor of Agriculture.
1838.*Wilson, Patrick, architect, 2 Queen Street.
1868. Wilson, Robert, engineer, Patricroft.
1867. Wilson, Thos., teacher, Forth School, Carnwath.
1860. Wishart, Edward, merchant, 3 Laverock Bank Terrace, Leith.
1864. Wood, John, surgeon-dentist, Dumfries.
1861. Wright, James, 13 Ainslie Place.
1836.*Wright, Robt., architect, 22 George Sq.
1863. Wright, Thomas Strethill, M.D., M.R.C.P.E., 55 Northumberland Street, *Vice-President*.
1859. Wyllie, J. S., 5 Viewforth Place.

1853. Young, James, chemical manufacturer, Limefield.
1859. Young, James, M.D., 36 Castle Street.
1860. Young, John, gas-engineer, Aspull, Wigan.
1861. Younger, Robt., brewer, Croft-an-righ.

TOTAL ORDINARY FELLOWS, 434.

The following ORDINARY FELLOWS are ordered to remain, till they return to Scotland, in the following

SUSPENSE LIST.

1845. Major-General Blanshard, R.E., Chatham.
1859. Richard S. Culley, telegraph-engineer.
1868. Henry Dixon, New South Wales.
1851. John S. Fraser, Great Western Railway, London.
1860. Captain Sir Wm. Hamilton, Bart., Royal Artillery, Simla.
1859. Alex. H. Lee, C.E., Calcutta.
1868. N. B. M'Dermott, Jamaica.
1862. A. T. Machattie, Ph.D., Ontario Chemical Works. London, Canada West.
1853. James Newlands, C.E., superintendent of works, Liverpool.
1846. Mungo Ponton, F.R.S.E., 11 Lansdowne Place, Clifton.
1854. J. T. Thomson, C.E., Government Surveyor, Otago.
1854. Dr Daniel Wilson, Professor, Toronto, Canada. TOTAL, 12.

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APPENDIX (F.)

Proceedings of the Royal Scottish Society of Arts, Session 1869–70.

First or Annual General Meeting, 8th November 1869.—David Stevenson, C.E., F.R.S.E., President, in the Chair.

The following communications were made :—

1. The President gave an address on the altered relations of British and Foreign industries and manufactures.

On the motion of Dr Stevenson Macadam, thanks were given by acclamation, and the President was requested to allow his Address to be printed in the Society's Transactions (see Vol. VIII., Part 1, page 101).

2. The Report of the Prize Committee, awarding the prizes for Session 1868–69 was read, and the prizes were delivered by the President to the successful Contributors.

(See Vol. VIII., Appendix C, page 25.)

The following Donations were laid on the table, and thanks voted to the respective Donors :—

1. Memoirs of the Literary and Philosophical Society of Manchester, Third Series, Vols. V., VI., VII. Presented by the Society.
2. Proceedings of the Royal Society, Nos. 112–114. Presented by the Society.
3. Journal of the Society of Arts, Nos. 868–883. Presented by the Society.
4. Engineering, Nos. 184–199. Presented by the Proprietors.
5. Scientific Opinion, Vol. II. Parts 8–11. Presented by the Proprietors.
6. English and Foreign Trade Gazette. July 1869.
7. The Artizan, Vol. III. Nos. 8–10. Presented by the Proprietors.
8. On the Supply of Animal Food to Britain. By W. L. Scott. Presented by the Author.

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9. Proceedings of the Institute of Mechanical Engineers. April 1869. Presented by the Institute.

10. Proceedings of the Institute of Civil Engineers, Vols. XXVII. XXVIII. Presented by the Institute.

11. Journal of the Royal Geological Society of Ireland, Vol. II. Part 1. Presented by the Society.

12. The Canadian Journal, Vol. XII. Part 3. Presented by the Proprietors.

13. On Hydrofluoric Acid. By G. Gore, F.R.S. Presented by the Author.

14. Modern Workshop Practice. By John G. Winton. Presented by the Author.

15. Report of the Smithsonian Institution, for 1867.

16. Reports of the National Academy of Sciences, for 1867–68.

17. Monthly Revenue Report. March 1869. Presented by the Smithsonian Institute.

18. Occasional Papers of the Boston Society of Natural History, I.

19. Proceedings of the Boston Society. May 1868.

20. Memoirs of the Boston Society of Natural History, Vol. I. Part 4. Presented by the Society.

21. Proceedings and List of Members of the Royal Institution of Great Britain. Presented by the Institution.

PRIVATE BUSINESS.

I. The Minutes of the previous Meeting were read and confirmed.

II. The following Gentleman was admitted as an Ordinary Fellow, viz. :—

Thomas Forrest, jun., Ironmonger, 29 South Clerk Street.

III. In terms of Law XV., the Society elected its Office-Bearers for Session 1869-70, as follows :—

R. W. Thomson, C.E., F.R.S.E., 3 Moray Place, *President.*

John Kippin Watson, F.R.S.E., 25 Waterloo Place, } *Vice Presidents.*
Thomas Ivory, Advocate, 23 Walker Street, }

Edward Sang, F.R.S.E., 2 George Street, *Secretary.*

John Scott Moncrieff, C.A., Chambers, 26 Frederick Street, *Treasurer.*

Stevenson Macadam, Ph.D., F.R.S.E., F.C.S., &c., Surgeons' Hall, Nicolson Street, *Editor of Transactions.*

Alexander Jamieson, 71 Adam Square, *Curator of Museum.*

Alexander Kirkwood, 9 St James' Square, *Medalist.*

Thomas Bell, 117 George Street, *Officer and Collector.*

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Ordinary Councillors.

ALLAN D. STEWART, C.E. 12 Castle Street.
WILLIAM FIRTH, Rose Villa, Viewforth.
JAMES GOWANS, Rockville, Napier Park.
ALEXANDER FRASER, Old Fishmarket Close.
ROBERT H. BOW, C.E., F.R.S.E., 7 South Gray Street.
JOHN PATERSON, C.E., 27 Hope Terrace.
ADAM MOSSMAN, Jeweller, 30 Princes Street.
CHARLES PEARSON, C.A., 128 George Street.
A. BREBNER, C.E., 84 George Street.
GEORGE HARRISON, Merchant, 12 Blackford Road.
CHARLES MACPHERSON, C.E., 10 Glengyle Terrace.
Professor FLEEMING JENKIN, F.R.SS. E. & L., 5 Fettes Row.

IV. A List of the Office-Bearers, and an Alphabetical List of the Fellows, as at 1st November 1870, had previously been sent to the Fellows.

V. A Copy of the Prize Committee for Session 1869–70, had also been sent.

Second Meeting—22d November 1869.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The President, on taking the Chair, briefly thanked the Society for the honour they had conferred upon him.

The following Communications were then made :—

1. On the Improvement of Achromatic Telescopes, by Thomas Davidson, Optician, Newcastle, was read and remitted to a Committee composed of Mr Alexander Reid, John Nicol, and Dr Strethill Wright, Convener.

2. On the Economic Distillation of Coal Gas from Cannel Coal, by Stevenson Macadam, Ph.D., F.R.S.E., was read and illustrated by Diagrams, showing the Quantity and Quality of Gas obtained from mixtures of Coal as contrasted with the Coals taken separately (see paper printed in the Transactions, Vol. VIII., page 131).

After a discussion, in which the President, Mr John Reid, and Mr Watson took part, the paper was remitted to a Committee composed of Messrs James Young, John Reid, and J. K. Watson, Convener.

3. Part 1 of Vol. VIII. of the Society's Transactions was laid on the table.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Engineering, Nos. 200–202. Presented by the Proprietors.

2. Journal of the Society of Arts, Nos. 884–886. Presented by the Society.

3. The Artizan, Vol. III. No. 11. Presented by the Proprietors.

4. Scientific Opinion, Vol. II. Part 12. Presented by the Proprietors.

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5. Proceedings of the Institute of Mechanical Engineers, for August 1869. Presented by the Institute.

6. Journal of the Royal Geological Society of Ireland, Vol. II. Part 2. Presented by the Society.

7. Proceedings of the Institute of Engineers in Scotland, Vol. XII. Presented by the Institute.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Candidate was proposed, balloted for, and admitted as Ordinary Fellow, viz. :—

William Hamilton Muir of Shawhill, 18 Picardy Place.

Third Meeting—13*th December* 1869.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communication was made :—

On Braced Arches and Suspension Bridges. By Fleeming Jenkin, F.R.SS., L. & E., Professor of Civil Engineering in the University of Edinburgh, and was illustrated by Models and Diagrams (see paper printed in the Transactions, Vol. VIII., page 135). After a discussion, in which the President, Messrs W. H. Muir, Bouch, and David Stevenson took part, the paper was remitted to a Committee composed of Messrs A. D. Stewart, John V. Day, and Robert H. Bow, Convener.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Engineering, Nos. 203–205. Presented by the Proprietor.

2. Journal of the Society of Arts, Nos. 887-889. Presented by the Society.

3. Scientific Opinion, Vol. II. Part 13. Presented by the Proprietors.

4. Transactions of the Institute of Engineers in Scotland, 1869. Presented by the Institute.

5. Report on Experimental Investigation into the Ventilation of the New Barracks at Chelsea. By F. De Chaumont, M.D. Presented by the Author.

6. The Home Life of Sir David Brewster. By his Daughter, Mrs Gordon. Presented by Mrs Gordon.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The Secretary intimated that he had received a letter from Mr Watson (Convener of the Committee on Paper No. 4211), stating that Mr James Young is from home and will not be back for some months, and requesting that another member of the Society be appointed in his place.

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Thereupon Mr G. F. Cusiter was appointed in place of Mr Young.

III. The following Gentlemen were admitted as Ordinary Fellows:—

1. Samuel Lack Mason, general manager of the North British Railway.
2. J. G. Tunny, photographer, 93 Princes Street.
3. William H. Davies, carver and gilder, 89 George Street.

IV. The following Resolution, recommended to the Society by the Council, was proposed and unanimously adopted, viz.:—"That the names proposed for the Prize Committee be printed in the Billet for the Meeting at which the Committee is to be appointed."

Fourth Meeting—10*th January* 1870.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communications were made:—

1. A paper on Sanitary Improvements, by James Kerr, superintendent, Sheriff Court-house, was read, and illustrated by help of diagrams and models.

The Author said,—With a view to forward the more general use of dry material, such as earth and ashes, in commodes and privies, a simple form of appliance now claims attention, as showing how any person may make, and how they may use earth-closets and urinals, which at best require more personal attention and scavenage in fetching and carrying than is generally supposed, and this difficulty will hinder the introduction of the dry earth system, as long as water can be used, or abused, as a vehicle to get quit of feculent matter anyhow, or anywhere, without the least consideration of the waste and want of the fertilising agents now run to pollution. The principle on which the dry earth system is advocated is so very simple, that the sanitary disposed cat daily gives us an example (unless when it falls from its first estate and becomes too domesticated). It has, since the creation, illustrated the Mosaic injunction, that dry earth should be freely used as a disinfectant. The Rev. Mr Moule has still further explained how every man may become his own scavenger, but no patent mechanical closet is required to expound such a text, as its application lies in the preparations—fetching and carrying of dry earths, &c., to absorb feculent matter, and so remove it profitably and inoffensively from the towns to enrich the fields. The dry absorbing closet and urinal being cheap, simple, and effective, may be used with advantage whenever there is some attention to its cleanliness for street privies, workshops, railway stations, schools, &c., and as commodes for hospitals, &c., and, with some extra scavenage, this earth closet may even be advantageously introduced into the densely populated houses in the old town of Edinburgh, from which the daily filth is emptied into

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the closes every night, the foul odour from which is drawn up into the houses above by the staircase acting as a foul air flue. One or two absorbing closets, with proper attention, in such staircase would prevent this.

The application of the earth closet to such dwellings in towns where water and drainage cannot be properly applied, is only suitable with the regular attention of the scavenger with such, and a daily supply of dry earth, or even by using the ashes from the dwelling, much of the filth would be at once absorbed and the foul smells prevented.

By having an elevator and shoot for supplying dry earth, and for removing deodorised filth along with the ashes, the earth closet would be even more wholesome than the water-closet in many a common stair in Edinburgh.

It is curious to note, that while we who are pent up grudge to utilise and bury filth in mother earth, our Yankee cousins, who boast a whole unbounded continent as theirs, readily adopt the earth closet. An American engineer writes as follows :—" It is not worth while to discuss here the relative superiority of the water-closet and the earth-closet, the only idea that it is sought now to enforce is, that by the aid of the latter, the well-known advantages of the former are placed within the reach of every person in the land."

By the simple use of dry earth in quantities that even the dust of a country road places within the reach of all, the waste of our bodies may be rendered immediately and permanently inodorous. It matters little (except for the question of convenience) what means are adopted for applying the earth—a barrel in the cellar with a seat over it, and a box of dry earth beside it—paper bags of earth to be used in connection with any suitable vessel, any arrangement, in fact, by which the faces may be covered with earth, will amply suffice, and the necessity either for going to a distant building, or of creating an offence in the house, is entirely removed. The requirements of the laws of health may be fully met without fear of exposure to danger, inconvenience, or annoyance.

It is chiefly important—

1*st*. That earth be not too sandy ; any fertile soil will do.

2*d*. That it be dried (and this may be done in the sun).

3*d*. That it be sifted (at least through a coal-sifter).

4*th*. That the bottom of the vessel be first covered with earth to prevent adhesion, and

5*th*. That enough earth (a pint or more) be thrown on the deposit to entirely cover it.

This is all. The deposits may accumulate in the house for a whole year, or they may be removed daily, as circumstances suggest. They will at no time be more offensive than so much earth from the garden.

Dry Earth, &c., used as an Absorbent in Urinals.

Agriculturists and horticulturists may yet find it profitable and advantageous to increase their crops by securing much of the fertilising matter now wasted in our polluted waters and vitiated air, by means of sun-dried

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earth prepared and stored up in dry weather for the use of earth-closets and urinals, &c., whereby much manure might be obtained at little cost, and of as much value as the far-fetched guano, which is generally more or less mixed with sand. The preparation and conveyance of enriched earth charged with feculent matter could surely, as a mercantile project, have a fair competition with sand and guano now that the demand for manures is increasing, and greater facility for conveyance allows of the waste of the city supplying the want of the field.

Civic economists might profitably consider how many tons of the best manure could be made daily at our street urinals, by absorbing all the ammonia and other agents by a process of filtration through earth, preventing the rather disagreeable smell which need not be wasted upon the city air were the earth urinals used and so constructed that the urine should not foul the walls, &c., but fall directly upon an earth-filter, which, charged with fertilising agents, could be daily removed and refilled with more sun-dried earth or even other absorbing materials.

Dr MacCormac, of Belfast, writes :—" That the utilisation of the urine is of yet more moment comparatively than that of the disposal of the solid fæces, for the urine you see represents all the nitrogen (or nearly all), and all the phosphates from the resolution of the bones,—matters of priceless value and importance to vegetation, and now almost totally lost."

The foregoing remarks may convey little further information than what may be known regarding the use of dry earth for sanitary purposes, but it is hoped that the few practical modes of application of the system now shown may tend to forward the more general use of the earth-closet and absorbing urinal, and so do good by lessening ill.

Sanitary Reform made more Effective at the Inlet of our Sewers instead of their Outlet, by the Agency of Sun-dried Earth for Absorption and Filtration of Sewage, Fæces, and Urine, also a new mode for the Tidal Utilisation of Sewage.

The supposed cleanliness and selfish comfort that the agency of water gives at the home end of the sewage-pipe, by being falsely used too much as a vehicle for the removal of filth, infringes a law of nature, and daily is increasing a vast physical social evil, causing wilful waste of health, and woful want of health, as has been too often illustrated at the outfall of sewers, and in streets and dwellings where the foul gases engendered in sewers are ever leaking out, and more or less doing mischief. We may, in fact, be in tribulation, like the overwhelmed wight in the Arabian Nights story, at seeing the nasty, gigantic evil we raise up, and vainly strive to overcome, by making costly efforts to do what is right at the wrong end of our sewers, forgetting that sewage reform, like charity, should begin at home. As by the agency of sun-dried earth and other dry material we may inoffensively at once absorb and retain all fertilising and putrifying matter from entering a sewer at all,—by such means every household in town may yield a grateful tribute to mother earth, and return as much manure from the refuse of the many hundredweights of bread and beef, &c., consumed as

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would grow the yearly supply of vegetables such as the cottager has for the produce of his kail yard. How many a citizen have we "of credit and renown" who does less for his country than the veriest clodhopper, and this arises from the fact that the application of dry earth as a disinfectant of feculent matter, requires the same personal attention to-day as it did when its use was first enjoined by Moses. The citizen now-a-days need not go a-field, as it will be even profitable to fetch dry earth from the country to mix with the dust of the city, and then be applied to absorb the refuse of the bounteous produce of the country, again to be returned by cart or rail from our town dwellings to enrich the soil. Having found no bread returns for all that we have cast into our polluted sewage waters, we may discover the truth of the wise man's observations, that "a bank of earth is a sure bank," so, by investing our muck by the ploughshare, we may expect a good dividend, and the blessing of those who are ready to perish would come upon us, by affording profitable employment as scavengers to thousands of our needy poor, who would be rescued from the pauper's lot and enabled to earn their own bread by helping to fertilise the soil by preparing manure from our worse than wasted sewage. Could we not also, in every city, raise an army of criminal sewage reforming scavengers, who, by being made to apply dry earth to reclaim the waste of fertilising matters in sewage, they may do good by lessening ill, and become the means of "making two blades of grass grow where only one grew before?" "God helps those who help themselves." We have advantages for conveyance of materials now that did not exist when Dutchmen, like our grandfathers, commenced depositing in water such a vast waste of manure. Surely, we cannot continue foolishly to waste in our waters at home the manure so much needed, that it has to be replaced by guano from the South Sea Islands, the supply of which keeps merchants and merchant fleets afloat.

There has been a great deal of talk about utilisation of sewage, but little reform has been effected as yet. The cost attending the application of sewage to irrigation, which may be almost impossible from the level situation of many towns, is not the only difficulty to such utilisation, as the foul stream, spread over the surface of the earth, may become a fertile source of fevers. What a hue and cry there has been about the coming evils from the level drainage of the new Infirmary when placed on the proposed site, and yet we have in the sewers, and at the outfall of the drainage from the present Infirmary, all the good and evil that can be said for or against our present sewage system, illustrated by the fortyfold enriched grass fields, from which the foul gases are carried by the wind over the city. The perfect cure for sewage evils must be effected by absorption or filtration in earth, and we will soon have to go the right way about applying it. We have, with all the enlightened skill of the age, striven in vain to get quit of sewage anyhow and at any cost, forgetting that it would be easier to stay the evils of sewage at the right end than at the wrong end of the sewage pipe. "Prevention is better than cure." So it must sooner or later come to pass that the sewage ghost that has so long defied all our engineering skill, will be quietly laid in mother earth. Meantime, by the proper application of dry earth for absorption and filtration

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retaining the fertilising properties of the sewage from such institutions as the Poor Houses of the city and St Cuthbert's parishes, the Lunatic Asylum, or even the new Infirmary, all the profitable agencies for enriching the soil may be got out of the sewage at either of these places by the daily removal in earth and ashes of a manure that can be prepared in a simple, inoffensive manner, giving some employment to the inmates, with far more profit and advantage to the community at large, than even from what is gained by the sewage as applied by the accident of situation at Craigentinny.

It has been proved, by analysis of sewage, that generally a ton of water is used as the vehicle to convey two-thirds of a pennyworth of fertilising matter from the city to the field, the cost of the water required being two-thirds of a shilling.

Is it not strange that this absurd costly system is still advocated, and proposed to be improved upon by still more ruinous expenditure for all dwellings, towns, and cities to have two sets of drains and sewers, one for foul sewage, and the other for rain and storm water, which, at best, will not do for the utilisation of feculent matter, what a very little personal attention, and some extra scavenage, could effect by the agency of dust and ashes removed daily from our streets, which would at once deodorise and absorb all that is now so very expensively wasted in water, and enable us by our city refuse more and more to enrich the country, every citizen bearing a hand in overcoming what is at least a social mess. If it is the personal dread of doing our duty by obeying a law of nature as to the disposal of dirt that hinders our sewage reform, surely we are getting far from the kingdom of heaven, if we must become as little children, whose delight is to dabble in it.

The proposed absorbing earth filter is simply a mode for the inoffensive daily removal of the sediment and fertilising matter left by the passage of the sewage through a thin bed of earth and ashes on a layer of straw, the comparatively pure water passing by ascension away into the sewer, where, flushed with the rain and storm water, it can do no further harm. The apparatus required may be simply described as a cast-iron come-at-able cesspool, by which a little extra scavenage in every street would profitably retain and daily remove most of the fertilising matter that now runs to putrid waste from every dwelling. By such a plan, the comfort and cleanliness of the water-closet is retained by the water used being so far cleansed by the earth receiving its own again, as was the first intention of those who first introduced the water-closet, but the evil lay in the want of such means as we have now for the daily removal of deodorised fæces and urine, by improved apparatus and conveyance, and hence the engineer of the period should strive to perfect a plan that enriches the earth, without polluting the waters or vitiating the air.

The utilisation of sewage, where it falls into tidal rivers or the sea, may be effected by having a relay of floating tanks or barges, that would, by rotation, receive the outfall, retaining all the sediment, and giving the overflow water a partial filtration. The rising tide would float the receiving vessels ready for despatch to fertilise the fields.

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The essence of sewage thus conveyed could flow from the vessel by means of a steam pump or pneumatic pipe and tank ashore, and thus absorbed in sun-dried earth, and so fitted for being conveyed as a rich manure to any part of the country.

In many cases a system of irrigation may be effected from the sewage vessel, as along the banks of canals fields may be irrigated at little cost.

The essence of sewage may be concentrated by the power of the tide, as in rising it shuts up the outfall of the sewer, the retained sewage would at once flow into the attached tank, and the tidal power may be employed there to force the overflow sewage water through an anscion filter, in such a manner, that the most of the fertilising matters are retained in a simple practical manner, and the pollution of rivers prevented by thus, as it were, completing the main sewage scheme.

After a discussion, in which the President, Messrs Lundy, W. H. Muir, Gowans, and J. Kerr, Dr Macadam, and the Secretary took part, the communication was referred to a Committee, consisting of Messrs Macpherson, Lundy, and J. Gowans, convener.

2. Description of a Mechanical Balloting Apparatus for Parliamentary and Municipal Elections, by James Davie, printer, was read, and illustrated by a model (see paper printed in the Transactions, Vol. VIII., page 157.) After some discussion, the communication was referred to a Committee, consisting of Messrs Milne, Sturrock, and Ivory—Mr Ivory to be convener.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 890–892. Presented by the Society.

2. Engineering, Nos. 206–208. Presented by the Proprietors.

3. Transactions of the Institution of Engineers in Scotland, 1869–70. Presented by the Institution.

4. Proceedings of the Royal Society, No. 115. Presented by the Society.

5. British and Foreign Mechanic, Vol. I. No. 13. Presented by the Proprietors.

6. Canadian Journal, Vol. XII. No. 4. Presented by the Proprietors.

7. Journal of the Scottish Meteorological Society, No. 24. Presented by the Society.

8. Miscellaneous Papers. By Joseph Whitworth, LL.D. Presented by Dr Whitworth.

9. Report of the Committee of the Workmen's Club and Institute Union. Presented by the Club.

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PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentlemen were admitted as Ordinary Fellows:—

1. John Thomson Maclagan, chemical manufacturer, 7 James Place, Leith.
2. George Roberts, builder, 1 Grosvenor Street.

III. In terms of Law XX., the Society appointed a Committee, of Messrs Tawse, Rainie, and Dickson, to audit and report on the Treasurer's books.

IV. The Secretary intimated that the Billet for next Meeting would contain a recommendation by the Council in regard to a Conversazione to be held in the Museum of Science and Art.

Fifth Meeting—24th January 1870.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communications were made:—

1. Report of Committee on Dr Macadam's Paper on the Economic Distillation of Coal Gas was read and adopted.

2. Suggestion of a Cheap Breakwater, by A. G. K. Borron, Lebanon Estate, Ceylon, was read, and, after remarks by the President, Messrs J. Leslie and Sang, was remitted to Messrs Andrews, Cay, and Alexander Leslie.

3. Description of the Atmometro-Hygrometer, by Peter Stevenson, instrument maker, George IV. Bridge, was read, and the instrument exhibited (see paper printed in Transactions, Vol. VIII., page 160.) After a discussion, in which Messrs Thomson, Sang, and Leslie took part, the communication was referred to Mr James Leslie, Dr A. K. Johnston, and Mr J. Nicol.

4. Description of an Apparatus for Registering Cab Fares and Distances, by William Inches, Dysart; together with,

5. Description of a Mechanical Register of Distances, or Hodometer, by Patrick Macfarlane, bank agent, Comrie—were read, and, after a few remarks by Mr W. H. Muir, the two communications were referred to Messrs A. Gray, R. Ritchie, and A. Fraser, convener.

The followieg Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 893–895. Presented by the Society.

2. Engineering, Nos. 209–211. Presented by the Proprietors.

3. Scientific Opinion, Vol. II. Part 14, and Vol. III. Nos. 62, 63. Presented by the Proprietors.

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4. Transactions of the Botanical Society. Presented by the Society.

5. The Artisan, Vol. III. No. 9, and Vol. IV. No. 1. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentleman was admitted as an Ordinary Fellow:—

Frederic M'Connel of Robgill, Kirtle Lodge, Trinity.

III. A letter from Professor Archer, offering the use of the Industrial Museum for a Conversazione, was read, which offer the Society accepted, and requested the President, Vice-Presidents, Secretary, and Treasurer to arrange the details.

Sixth Meeting—28th February 1870.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communications were made:—

1. Report of Committee on Mr James Kerr's Paper on Sanitary Improvement—Mr Gowans, Convener—was read and adopted.

2. Report of Committee on Mr Davie's Ballot Register—Mr Ivory, Convener—was read and adopted.

3. Report of Committee on Mr Borron's Suggestions of a Breakwater—Mr Alexander Leslie, Convener—was read and adopted.

4. The Society appointed Professor Smyth as Convener of Committee on Professor Jenkin's paper, in place of Mr R. Bow, who had declined to act.

5. Proposed Compensation in Clocks and Watches, by Patrick Macfarlane, banker, Comrie, was read, together with the next paper on the same subject, viz.—

6. Compensation of the Pendulum for Changes in Temperature and in Atmospheric Buoyancy. By Edward Sang, F.R.S.E., (see paper printed in the Transactions, Vol. VIII., page 163.) After a discussion, in which the President, Messrs Reid, Bow, Sang, Robertson, and Ferguson took part, the two papers were remitted to Messrs G. Cousin, Alexander Macnaughton, and Professor Smyth.

7. Description of an Improved Method for Evaporating Cane Juice, by the Hon. William Hossack, Buff Bay, Jamaica, was read, and, after remarks by the President, Messrs J. Johnstone, Cox, and R. Bow, was referred to Messrs Blanshard, Campbell, and J. Johnstone.

Mr W. H. Muir, after noticing the great success that attended the Conversazione of the Society held in the Industrial Museum on the 14th inst., moved a vote of thanks

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to Professor Archer for his kindness in giving the use of the Museum, and also to those gentlemen who took charge of the arrangements, which motion was adopted by acclamation.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Proceedings of the Royal Society, Nos. 112-114. Presented by the Society.
2. Journal of the Society of Arts, Nos. 896–900. Presented by the Society.
3. Engineering, Nos. 212-216. Presented by the Proprietors.
4. The Artizan, Vol. IV. No. 2. Presented by the Proprietors.
5. Proceedings of the Institute of Mechanical Engineers, Part 2, 1869. Presented by the Institute.
6. Transactions of the Institute of Engineers in Scotland, 1869-70. Presented by the Institute.
7. Scientific Opinion, Vol. III. Nos. 64–68. Presented by the Proprietors.
8. Report of the British Association, 1868. Presented by the Association.
9. Microscopic Objects figured and described by John H. Martin. Presented by the Publisher, John Van Voorst, London.
10. Journal of the Institute of Actuaries, No. 78. Presented by the Institute.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentlemen were admitted as Ordinary Fellows:—

1. Robert Reston Horne, Kennuirhill Colliery, Toll Cross, Glasgow.
2. Wilson Hartnell, Engineer, 65 York Place.

Seventh Meeting—14*th March* 1870.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communications were made:—

1. Report of Committee on Mr Inches' Register for Cab Fares—Mr Fraser, Convener—was read and adopted.
2. Report of Committee on Mr Macfarlane's Hodometer—Mr Fraser, Convener—was read and adopted.
3. Description of a New System of Propelling Vessels, by the Hon. William Hossack, Buff Bay, Jamaica, was read, and illustrated by drawings. After a discussion, in which the President, Secretary, and Mr Cox took part, thanks were awarded to Mr Hossack for his Communication.
4. Description of a Machine for Cutting Willows. Designed by Thomas

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Well, Basket-maker, Edinburgh Blind Asylum, was read, and the machine exhibited in action.

The author said,—In cutting the willows to the different lengths required for basket making, the workers in the Blind Asylum have hitherto to use a pair of hand clips, each stick being measured off and cut singly. This method, while it was severe on the hand, especially when thick sticks had to be cut, took considerable time. It occurred to me that if a machine could be contrived to cut a number of sticks of one length at once, great saving both of labour and of time would be attained. The result of my cogitations, along with the help which I have received from Mr Elmslie Sang, is the machine which I now submit to the Society.

It consists, first, of a shallow trough for receiving the willows, about four feet long and six inches wide. At one end a knife is placed, working on an axis a little out from the back of the trough ; this knife is worked by a strong lever, placed to accommodate the operator's right hand. For the purpose of regulating the length of the pieces to be cut, a sliding stop is fitted to the trough. This stop can be set to the required distance by means of notched divisions along one edge, and can be secured there by half of a screw. In order to secure the willows while being cut, a strong iron bar or holder, working on the end of the knife-axis, is brought down ; this bar is elongated backwards for the purpose of being caught by a lever worked by the knife-handle. This lever is pushed under the tail of the holder when the knife is brought a little way down, and before the knife has begun to cut, the holder has secured all the willows which may be in the trough. To meet any inequalities which may be among the thicknesses of these, the holder is faced with elastic gum.

When the knife is raised, the lever is drawn from under the tail of the holder, which can then be lifted up to allow of the removal of the cut willows.

To enable the holder to take firm hold of different thicknesses of willows, the tail-end is bent up a little, and the lever, which is pushed under it, is made to work in an elongated hole, and a spring is placed so as always to press the lever toward the trough. When a bundle of thin sticks is to be cut, the lever easily passes below the tail of the holder and prevents its rising. But when thick sticks are introduced, the lever can only get a short distance under the tail, the point or fulcrum of motion is then transferred from the centre-pin to the end of the lever where it has been met by the tail of the holder ; the yielding of the spring then allows the knife to finish its work.

On the outer side of the knife and a little distance, a guard is placed. The edge of this guard comes against the projecting ends of the willows, and bends them down a little before the knife begins to act ; by thus keeping the willows bent and the cuts open, this guard greatly facilitates the operation.

After a few remarks by Mr Cox and the President, the Communication was referred to Messrs Alexander Whytock, J. D. Park, and John Milne.

5. Suggestions of a Universal Alphabet, and Mode of Writing and Printing for the Blind. By Edward Sang, F.R.S.E., was read, and for

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which thanks were accorded (see paper printed in the Transactions, Vol. VIII., page 170.)

6. Improvements on Stop-Cocks. By R. H. Bow, C.E., was read, and an Improved Stop-Cock exhibited.

The author said,—The benefit to be derived from adopting a stop-cock, in which the plug would be constrained always to rotate in one direction, was pointed out to me more than a year ago by Mr Peters, of Dundas Street, and therefore should the Society think the subject of this paper of any value, it is to Mr Peters that the merit is properly due.

Mr Peters found that a stop-cock worked on this principle would keep tight for an astonishingly long time, as the wearing was regular, and tended always to a better fit of the parts.

When, on the other hand, the motion of the plug is restricted to little more than a quadrant in extent, and takes place alternately in opposite directions, as in the fitting up of hand-basins, kitchen-boilers, &c., the destruction is very rapid. Indeed, the certainty of leakage in the case of the hand-basin cock is so notorious, that the plumbers regularly supply along with it a little leaden tray to catch the tricklings, and a tube to convey these away from the tray to the waste-pipe. In one case that occurred in my own experience, the leakage was considerable before the cock had been used 1000 times, and was then discovered from the accident of the tube leading from the tray to the waste-pipe having become choked by debris of plaster dislodged by the carpenter when fitting up the basin.

The desirableness of a rotation of the plug in one direction only being made out, it is a simple matter to devise mechanical means to improve it.

A pallet spring acting upon ratchet teeth between a handle and the plug to hold in one direction only, would probably be the first plan to suggest itself, and such might in some cases be used ; but for more ordinary circumstances it is an advantage to get rid of any dependence upon springs.

From among other plans that have occurred to me, I shall select one that is simple and promises to be effective and durable. In it the handle part of the plug is connected with the plug by a suitable screw, so that when turned in the proper direction it holds firmly, but if turned in the wrong direction it unscrews itself instead of turning the cock.

In order that the screw should not become frictionally jammed, and therefore be more difficult to start than the plug, the screw should be one of long pitch, and the bearing should either be on the contracted end of the male screw, or a nick in the lip of the screwed tube should engage a stud fixed in the neck of the male screw, as shown in one of the drawings. In either case it will be easy enough to ensure that the handle will lie across the direction of the flow when the cock is shut.

I may point out another advantage of quite a different kind which such cocks would possess. They may be used as locked ones, for we have only to unscrew the small handle piece and carry it away with us as we would do the key of a lock ; and the cock might be quite as difficult to turn without it, as some of the common sort of locks to be opened without their *own* keys.

After remarks by the President, Secretary, Mr Cox, and Mr Peters, the

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Communication was referred to Messrs J. Sturrock, J. Lessels, and J. Reid.

The following Donations were laid on the Table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 901–902. Presented by the Society.
2. The Artizan, Vol. IV. No. 3. Presented by the Proprietors.
3. Scientific Opinion, Vol. III. Nos. 69–70. Presented by the Proprietors.
4. Engineering, Nos. 217–218. Presented by the Proprietors.
5. Address of Charles Blackie Vignoles on his election as President of the Institute of Civil Engineers. Presented by Mr Vignoles.
6. Address to the Students of the School of Art, Edinburgh, by Sir William Stirling-Maxwell. Presented by the Board of Manufactures.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

Eighth Meeting—28*th March* 1870.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communications were made:—

1. Improvements in Couplings for Railway Carriages, by James Mackenzie, Manager's Department, North British Railway, was read, and illustrated by a model and drawings (see paper printed in the Transactions, Vol. VIII., page 188.) After remarks by the President, the Communication was referred to Messrs Stewart, Bouch, and James Milne.
2. On the Source and Cure of Griddling in Planeing Machines and Lathes, by Edward Sang, F.R.S.E., was read, and after remarks by the President, Mr Reid, and Mr Milne, thanks were accorded to Mr Sang.

The following Donations were laid on the Table, and thanks voted to the Donors:—

1. Transactions of the Royal Society of Edinburgh, Vol. XXV. Part 2.
2. Proceedings of the Royal Society of Edinburgh, 1868–69. Presented by the Society.
3. Journal of the Society of Arts, Nos. 903–904. Presented by the Society.
4. Engineering, Nos. 219–220. Presented by the Proprietors.
5. Transactions of the Institute of Engineers in Scotland, 1869–70. Presented by the Institute.
6. Scientific Opinion, Vol. III. Nos. 71–72. Presented by the Proprietors.
7. Maw Son & Thomson's Quarterly Price Current, with Illustrations. Presented by Messrs Maw Son & Thomson.

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PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentleman was admitted as an Ordinary Fellow:—

George Pratt Boyd, Gas Manager, Alloa.

Ninth Meeting—11*th April* 1870.—R. W. Thomson, C.E., F.R.S.E., President, in the Chair.

The following Communications were made:—

1. Report of Committee on Professor Jenkin's paper on Braced-Arches—Professor Smyth, Convener—was read, along with letters from Mr Stewart and Mr Bow. After a discussion, in which the Secretary, President, Messrs Bow, Bouch, Ivory, Moffat, R. M. Smith, Reid, and Stewart took part, the paper was again referred to the Committee, and the Secretary was requested to send them a statement of what he had said that evening to the Society.

2. Report of Committee on Mr Macfarlane's Compensation for Clocks and Watches—Professor Smyth Convener—also

3. Report of Committee on Mr Sang's Compensation of the Pendulum for Changes in Temperature and in Atmospheric Buoyancy—Professor Smyth, Convener—were read and adopted.

4. Report of Committee on Mr Bow's Improvement in Stop-Cocks—Mr John Reid, Convener—was read and adopted.

5. Notice of a New Method for Warming and Ventilating Buildings, by Robert Aytoun, W.S., was read, and after remarks by the President, Messrs Moffat, Morrison, and Smith, the Communication was referred to Messrs Lessels, Moffat, and Gowans.

Dr Cowan's paper on Channel Railways was delayed on account of the lateness of the hour.

The following Donations were laid on the Table, and thanks voted to the Donors:—

1. Proceedings of the Royal Society, No. 117. Presented by the Society.

2. Journal of the Society of Arts, No. 905. Presented by the Society.

3. Engineering, No. 221. Presented by the Proprietors.

4. Scientific Opinion, Vol. III. Nos. 73–74. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentleman was admitted as an Ordinary Fellow:—

Robert Scott, manager of the Addiewell Paraffin Oil Works.

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III. The Report of the Auditing Committee on the Treasurer's Books was read, and the President granted discharge to the Treasurer in terms thereof.

IV. The recommendation of the Council, that the Society make an addendum to Law V., as follows :—" Persons residing out of Scotland, who may apply for admission and be Elected as Ordinary Fellows, shall pay the Composition of Ten Guineas, and thereby become Life Members," was proposed by the President, and approved of.

Tenth Meeting—25th April 1870.—John Kippen Watson, F.R.S.E., Vice-President, in the Chair.

The following Communications were made :—

1. Report of Committee on Mr Davidson's Improvements in Telescopes—Dr Strethill Wright, Convener—was read, and at the request of the Committee, the paper was again recommitted.

2. Report of Committee on Mr Hossack's Mode of Evaporating Cane Juice—Mr James Johnstone, Convener—and

3. Report of Committee on Mr Thomas Well's Machine for Cutting Willows—Mr John Milne, Convener—were read and approved.

4. Description and Criticisms of the Various Schemes proposed for Communication across the English Channel, by Thomas William Cowan, C.E., Ph.D., &c., was read and illustrated by Drawings. After remarks by Mr Bouch, the paper was referred to Messrs Bouch, Jopp, and Stewart.

5. A New Planisphere for showing the Altitude and Azimuth of the Sun or Star, by John Love, Royal Bank, Greenock, was read, and the Instrument exhibited (see paper printed in the Transactions, Vol. VIII., page 173.) After remarks by the Secretary, the communication was referred to Dr A. K. Johnston, Professor Jenkin, and Dr Ferguson.

On account of the lateness of the hour, Professor Smyth's Paper on an Equal-Surface Projection for Maps of the World was delayed.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 906–908. Presented by the Society.

2. Engineering, Nos. 222–224. Presented by the Proprietors.

3. Scientific Opinion, Vol. III. Nos. 75, 76. Presented by the Proprietors.

4. Proceedings of the Institute of Mechanical Engineers, Nov. 1869. Presented by the Institute.

5. Handbook of Estimates for House Furnishing. Presented by Richard Whytock & Co.

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PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. A Printed Abstract of the Accounts of the Society, for Session 1868–69, was enclosed in the Billet for this evening.

III. The following addendum to Law V., which was recommended by the Council, and approved of by the Society at last Meeting, was proposed and finally adopted, viz.:—"Persons residing out of Scotland, who may apply for admission and be Elected as Ordinary Fellows, shall pay the composition of Ten Guineas, and thereby become Life Members."

Eleventh Meeting—9th May 1870.—R. W. Thomson, C.E., F.R.S.E., in the Chair.

The following Communications were made:—

1. Report of Committee on Mr Mackenzie's Couplings for Railway Waggons—Mr Reid, Convener—was read and adopted.

2. On an Equal-Surface Projection for Maps of the World, by Professor E. Piazzi Smyth, F.R.S.E., Astronomer Royal for Scotland, was read and illustrated by Drawings, and afterwards referred to Professor F. Jenkin, and Messrs Ivory and Ferguson (see paper printed in the Transactions, Vol. VIII., page 192).

3. Notice of Improvements on the Mode of Collecting Bilge Water in Ships, by Heriot Currie, Chief-Engineer, N. 4 S. Pharos, was read and illustrated by Drawings and Models (see paper printed in the Transactions, Vol. VIII., page 204.) After a few remarks by the President and Mr Miller, the communication was referred to Messrs Rose, Bennet, and D. Stevenson.

4. Description of a Safety Apparatus for Coupling Waggons, by William Noble, Engineer, was read and illustrated by a Drawing and Model, and afterwards referred to Messrs Bouch, Reid, and Stewart.

The author said,—This is a description of a safety apparatus for coupling railway waggons, which consists of a hook and two links, with a crank lever.

Description of the Hook.—It is simply a hook with a plane end with two holes in it in a straight line with the centre of the hook for the links. A piece of iron is riveted on to each side of hook between the holes, and is bent at right angles from the top edge of hook, the other end projects by the edge and is curved from each other; this allows the crank to give the motion to the nook and links.

The top link is for connecting the hook to the draw rod of waggons,

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which has an oblong hole in the end of it; the other link is for coupling to the opposite hook of waggon.

The crank lever for lifting the hook and links is a rod of iron, bent in the centre like a crank, the ends bent nearly parallel to the crank to act as levers or handles. This runs across the end of waggon, the crank hanging perpendicular behind the hook and links, the lever hanging over the *outside* of the buffers.

When the waggons come together for coupling, the guard takes hold of the handles on each end of waggons, moving the one handle before the other, which allows the crank to lift its hook and to keep it clear of the opposite one, and conducts the bottom link into the opposite hook; lowering the hook completes the coupling.

To uncouple only requires one handle to be wrought.

They will couple in any working position the waggons are in, also when they are coupled there is but one link not in use.

The advantages that I claim for my invention are—

1*st*, That no person is required to go between the waggons either to couple or uncouple them, as all the changes are wrought entirely from tho *side* of the waggon, and not from the *ends* as is presently done; and

2*d*, That the expense of making the necessary alterations to fit the present waggons with the new apparatus will be easily done, and will cost very little.

5. Description of a Self-Registering Rain-Gauge, by James L. Watson, Executive Engineer, Madhapoor, Punjaub, communicated by Mr Dods, was read, and the Rain-Gauge exhibited (see paper printed in the Transactions, Vol. VIII., page 225.) After remarks by Mr Bow, Professor Jenkin, the Secretary, and Mr Cox, the communication was referred to Messrs P. Stevenson, Alexander Leslie, and G. Romanes.

6. Improvement in Hydraulic Mains for Gas Works, by George Pratt Boyd, Gas Engineer, Alloa, was read and illustrated by an Experiment and Drawings, and referred to Messrs Watson, Cusiter and Reid.

The author said,—In introducing the subject of this paper it may be as well to state that it is the experience of all gas managers that a grievous evil, or rather impediment, arises in the very first part of the process (I attribute that to the system of, or rather the general arrangement and working of, the hydraulic main), which is very difficult to remove, besides being destructive to the retorts in the course of removal. There are other two evils, pitch and chokes, that, but only when, what we term good heats, the competitive price that gas is now sold at, has done much to bring on the chokes and pitch, as nothing else than good heats will do now to get all the gas out of the coals. But carbon gathers with low as well as high heats (as it is proverbial, prevention is better than cure), by keeping the carbon from gathering in the retorts is better than the most improved means of removing it. By keeping the carbon from gathering, the pitch and chokes are among the things that were, being entirely removed and done away with by a simple arrangement in the hydraulic main.

The hydraulic main, as is well known, is the reservoir or large pipe on the top of the retort bench for collecting the gas from the retort dip pipes.

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The hydraulic main is, so far as I have been able to ascertain, made to a diameter round or D-shaped. It is generally kept more than half full of water, or rather tar (the water giving place to the tar as it comes along with the gas from the retorts) for the purpose of sealing the ends of the dip-pipes, which are carried down into the tar to the depth of from one to three inches, according to what the engineer may think safe. By the ends of the dip-pipes being sealed in the tar a perfect joint is formed, and a self-acting valve of the most perfect order, as by it the gas is kept in the hydraulic main, and cannot escape back into the retort while it is open and being charged, or into any of the retorts that may not be in use at that time.

In explaining this improvement it will be necessary to go back and point out the defects as experienced by myself in the ordinary working of the hydraulic main. My first experience was with a round hydraulic main, of twelve inches diameter, and a seal of three inches on the dip-pipes, which caused a considerable quantity of carbon to accumulate along the whole length of the retorts, which was difficult to remove, and most destructive to the retorts in its removal. It having to be done with sharp iron pinches, great care had to be exercised for fear of going through the sides, especially if the retort had been any time in use. I was also troubled with pitch gathering at the bottom of one of the dip-pipes. By cutting one inch off the end I was relieved, and by giving one inch less seal I had no more trouble with it on that score; but still the carbon, as the bridge pipes were nearly level, and had not much of a run, a considerable quantity of thick tar accumulated in them, which had to be removed by red hot rods thrust from a hole in the back of the ascension pipe, or the passage for the gas would have closed entirely up, thereby causing a great deal of trouble and annoyance both to myself and the retort house men. I may say here that I opened the end of the hydraulic pipe the first opportunity to see if pitch was in it, but found none, the tar being quite liquid, so that showed me it was the heat and depth of seal that caused the pitch. Some time after that I cut one inch off the top of the overflow pipe, thereby lessening the seal by another inch, which did keep the carbon from gathering so fast. Previous to that the retorts had to be scruffed every week, but after that once a month kept the retorts comparatively clear of carbon, but a gradual closing up at the back end, as it is most difficult to get out the carbon from the back end.

I having made an alteration in the retort house, fitted up a 20-inch D-shape hydraulic main, put it on the top of the retort bench, the 12-inch round one stood out in front of the retort bench on columns, giving the dip exactly one inch of seal. So exact was I that I had the ends of the dip turned so as to have all the same depth, and quite even all round the low end; but having improved the retort ovens in the heating department, the arrangement did not suit, as I was troubled with pitch, chokes, and carbon.

I again tried another experiment by putting in an overflow pipe, giving the dip-pipes only one half inch of seal in the tar, which removed the pitch and chokes; but I was still troubled with carbon: but a scruffing once in six weeks or two months kept the retorts remarkably clean. I sometimes burned out the retorts with cold air carried to the back end of the retort with a kneed pipe, using the ascension pipe for a chimney, which removed

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the carbon entirely in a few hours, but destroyed the retorts considerably, as the cold air left great cracks or ruts, which caused the carbon to come on again quicker than before. Wishing to be relieved still further of the carbon, I again tried another experiment about four years ago, by putting a guard over the overflow pipe, hung by snugs, so as the under edge of the guard might be two inches below the top of the overflow pipe, the top being two inches above the overflow pipe, with a passage for the tar to flow up between the overflow pipe and the guard to the tar well, thereby leaving two inches of water on the top of the tar for the dip-pipes to work in instead of tar, the water being displaced by the gas coming from the retorts with about half of the pressure that it took to displace the tar. The experiment has been working most satisfactorily ever since, having never required to be touched, altered, or adjusted since first fitted, about four years ago, and is still doing all the work that could be expected, much to the comfort and satisfaction of both myself and the retort house men, never having had to scruff a retort since it was fitted up. The guard requires no attention, and is not liable to go wrong after being fitted on. The carbon being kept from gathering on the retort, must add considerably to the quantity and quality of the gas, as the carbon is the heaviest complainant part.

Any hydraulic main now in use could easily be fitted with a guard at the cost of a few shillings, whether the gas, tar, and water went off at the end of the hydraulic main or the gas went off at the top; and the tar and water at a pipe topped on the end at the required level by placing a guard kneed at both ends to allow a free passage for the tar to pass up between the guard and the end of the main, and run off to the tar well in the ordinary course. Some may say that it is not safe to work with only one half inch of seal on the dip-pipes, as the tar or water would be apt to flow over the top of the dip-pipes and allow the gas to escape into the retorts that might be open through being charged or idle; but I have tested for that effect several times to satisfy myself, and found that a back pressure of twenty-two inches could be put on the hydraulic main, and no water come over the top of the dips into the retorts that were idle and standing open, and of course there was no escape of gas. Had the retorts had a seal of two or three inches in tar or water, the tar or water would have been running over the top of the dips into the idle retorts with the twenty-two inches of pressure. When I tried the twenty-two inch pressure on the hydraulic main the tar rushed out of the condenser chest, and would have emptied it, had the pressure continued a short time longer, but made not the slightest disturbance in the hydraulic main. A hydraulic main of twenty-four inches could be wrought in perfect safety with a seal of one-fourth of an inch, without either tar water or gas flowing over or escaping by the idle dip-pipes. I consider it safer and better to work with one-half seal in water without an exhauster than with a seal of three or four inches in tar and an exhauster; for if the exhauster was worked at a vacuum of two or three inches it would be apt to draw in atmospheric air, which would be detrimental to the quality of the gas, unless the exhauster got its complement of work to perform.

An alteration in the shape of the hydraulic main might also be made to

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some advantage. Instead of being a round or D-shaped pipe, an oblong-shaped chest, with an arc of a flat circle from the bottom of the sides so as to allow of a hollow two inches clear from the bottom of the dip-pipes, which would form a kind of gutter for the tar to remain in, and leave enough of space for the gas to pass from the dip-pipes to the top of the tar or water, as it may be as well hard metal below what may be required for the gas to pass in leaving the dip-pipes. There is no use of having eight or ten inches of tar being always in the hydraulic main, as it serves no good purpose, so far as I can see, but adds weight on the retort bench, and is a useless tar-well.

7. Suggestions of a Process for Producing Maps Typographically, by John Skirving, Letterpress Engraver to the Bank of England, Haddington, was read, and specimens of the Printing and Types shown.

The author stated,—In bringing before your Society as a subject for consideration and discussion, the applicability of letterpress to map printing, it is fortunately unnecessary to enter on any detailed account of the history or of the art of printing: the mysteries of that craft have passed away, its terrors have subsided, the retrograde party who urged its extinction, and cried aloud, "put down printing or printing will put down us," yet lives, but resorts, itself, though in vain, to printing as a bulwark against the ever advancing tide of intellectual progression; and mankind, unscarred, unskaithed by meaningless anathemas, has settled down to the pleasing enjoyment of the intellectual luxuries, and the moral blessings of that transcendant, that inestimable discovery. Nor need a description of type founding detain you; or how, from rude carvings in wood, then in lead, the art crept onwards through successive improvements till it culminated in the most perfectly accurate and most exquisitely finished productions which the hand of man has ever made, I mean steel punches, all being aware that by means of moveable types our books and newspapers are produced, cheaply, effectively, but not mysteriously. Chemistry has ever been pre-eminently the science of wonders; printing its reliable exponent and remembrancer. Still, in a mixed assembly, some will be the better enabled to follow my subsequent suggestions for map printing typographically, by its being explained to them that in this country all typefounders now make their types of a uniform tallness, or as it is termed "height to paper," and that types are invariably rectangular.

There are types called spaces and quadrats, which, from their being shorter than printing types, are used to separate words from each other; these, of course, being shorter, receive no ink from the inking-roller, nor communicate any impression to the paper.

To the proper understanding of my contrivance for producing maps, those who are more familiar with printing will bear with me while I explain to the uninitiated that types are of various sizes in the stem, or the "body,' as it is technically called, and have accordingly definite distinctive names, such as English, Pica, Small Pica, Nonpareil, &c., and when to these names the prefix "two line" is added, the body is understood to be double the size, thus "two-line Pica" is about a third of an inch, Pica being as near as may be one-sixth of an inch. The size called Nonpareil is exactly half

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the size of Pica, and if there were such a body as half Nonpareil we should possess these sizes—

Two-line Pica = $\frac{1}{3}$rd of an inch.
Pica = $\frac{1}{6}$th ,,
Nonpareil = $\frac{1}{12}$th ,,
Half Nonpareil = $\frac{1}{24}$ h ,,

The short type called a quadrat, or, technically, an "em quad," has the same thickness as its body. There are, therefore—

36 Pica quads in a superficial inch.
144 Nonpareil quads ,,
576 Half Nonpareil quads ,,

Here, then, the printer can procure the means of concentrating 576 distinct separate quadrat types in the small space of a superficial inch, or of diversifying that concentration by distributing it betwixt those other proportional parts of a superficial inch. But I must not omit to mention that there are such discrepancies in the standards of the different typefounders, that scarcely any "body," though bearing the same name, is precisely of the same size in one foundry as in another. This is a serious matter for the printer, but we have little to do with it; such irregularities are no obstacle to the production of maps, for, as may be seen in this impression, the letters employed for names of places are minion body, reduced by the file to emerald body, the convenient basis on which I have started.

Referring to the compositor's department, it will be obvious to all that the various width of the letters of the alphabet involves a corresponding inequality in the breadth of the various types, though the body of each sort is equal throughout the alphabet; an advantage results from this inequality in breadth and uniformity in body; the compositor is enabled by the uniformity in body to secure straight lines horizontally, while by the irregularity in the breadth of the various letters, the types vertically, so to speak, support each other by their bearing on one, two, or three others in the lines immediately below or above them. Were a page of types composed exclusively of quadrats of uniform size, it were scarcely possible to secure them perfectly at right angles to each other, I speak of microscopic accuracy, and the bearing of these preliminary remarks on what follows will be obvious as I proceed.

In ordinary book work, the compositor arranges types in parallel lines in a composing stick, then transfers them collectively to the chase; in this state they constitute the form to be printed from: it were inconvenient to follow this method of arranging types in composing a map, because of the necessary intermixture of various bodies. I find it the much easier way first to set up a forme, say of Pica em quads exclusively, and to the size required; and having previously lotted out the engraved map, drawing, or photograph to be copied into squares of the same size, that is, into divi-

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sions equal to Pica em quads, I lift an em quad out of the forme, then fill up the vacant space with such fractional parts of Pica, namely, Nonpareil and half Nonpareil types, as are suitable, and are together equivalent to that vacancy. By this method quadrat after quadrat is removed where necessary, and square after square is refilled where required, the result is an embryotic approximation to the copy. Here I may mention that at present my map is composed of dots exclusively, except where roads, railways, and names of places occur, and it may surprise some to be assured there are only five different types or sorts used in this first experiment, exclusive, of course, of the letters for names of places. I thought a section of a Government map for my experience preferable to anything else I might have selected ; if I could not do a part it were useless to try more ; on this account I chose section 2 of the county of Haddington, as being amply diversified in character.

It may interest those who have never thought much about printing or typefounding to be informed that before a printer can possess himself of a complete fount of types of one size only he has to purchase some 250 different characters—capitals, small capitals, and lowercase of Roman and of italic, figures, marks of punctuation, fractions, signs, rules, leaders, accents, references, &c., and that the original steel punches from which these types were necessarily made in the first instance were engraved for the typefounder, and at great expense. Hence the costly plant of the printer not many years ago ; but science is progressive, and manufacturers must keep pace with its discoveries.

I well remember some thirty years ago, while yet a member of this Society, and when electrotype was just discovered, that prizes were offered by the Society for improvements in electrotype, and specially for such improvements as would enable parties, without being at the expense of original punches for themselves, to electrotype matrices from the types of others. There was no copyright act then, nor is there any yet, to protect against such legalised robbery; but I protested at the time against what I considered unfair, unworthy. I stigmatised the practice as dishonourable, as literary piracy. The insatiable appetite for cheapness and quantity prevailed over nobler considerations. We see the result now; few or no originals are produced at all ; we have come to a stand-stlll in typographic novelties. However, there is no good unaccompanied with some evil—no evil of untempered severities.

Yet of the punch-cutters of that period some fled to America. Electrotype and grosser unscrupulousness were there before them. Some pined away in poverty and consumption, one died in a mad-house, one rashly rid himself of life. Well, in bitterness of soul, may some exclaim, " *You* take my life when you do take the means whereby I live."

But, I repeat, the types used in composing this map are only five in number, sufficient to demonstrate the feasibility of the principle of the applicability of types to the production of maps ; it will be time enough to make other useful varieties when required. I, who am not a compositor, experienced no difficulties in setting it up ; you whose business it is should find none.

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Possessed of, say, nonpareil type, like this, ⁘ three rows of dots, six in each line, and justified as an em quadrat, water—I mean ocean, sea. and the like — is very creditably represented. Approaching shores or islands, other two types are required to accommodate inequalities of beach; and these, bearing in mind the principle of proportional sub-division, must be cast on half nonpareil ems, thus ⁖ and thus ⁝, the former to line with the upper row of the nonpareil type, the latter to line with its two under rows of dots. (The types are here should any one desire to examine them.) You now understand the use of three of the five types; the other two, also cast on half nonpareil ems, are of these characters, ⋯ ⋯ ⋯ ⋯ each having three rows of dots, three on each row. The first enables you to construct a bold margin for the sea shore; the second, in juxtaposition, softens or tones down the otherwise too abrupt transition to something darker than the sea, yet lighter than the land margin. It will immediately occur to you that, with a pointed graver, it is easy to remove one, two, or more of the nine dots to indicate the precise shape of the coast. The same remarks apply to the formation of islands. You have sixteen positions in which either of these two types can be placed, within the 36th part of a superficial inch. Each type having nine dots upon it, there therefore occur no fewer than 5184 dots in a single superficial inch, either or all of which can be removed or be retained at pleasure.

We come now to the land question, and can dispose of it quickly, or, as in another place, amend its details in committee.

Where woods and plantations occur I find it a simple matter just to place together, alternately, the last two types I spoke of. They answer quite as well as anything else I am prepared to suggest, and far more economically. What were the use of encumbering you with a score of varieties of types to represent trees and bushes? You will see the inconvenience and the impolicy of charging yourselves with the cost of them. The dendrology represented on existing maps never had existence in nature, and is of about as much practical importance there as the ever-shifting footpaths so elaborately and so superfluously indicated on the Links or on the sea beach. The distinct indication of a parish boundary or of a highway you can appreciate, but really not so the private cartroad to a farm steading, nor the precise conformation with perhaps the exact nautical bearings, too, of an adjoining cattle-pen. I take it that the essentials in a map are distinctness and accuracy—not illegible superfluities, not such useless and ridiculous excess as reminds you of the Lord's Prayer engraved on a sixpence, or the perplexing intricacies of the maze in the Botanic Garden. A saving clause may here be introduced. The Ordnance Survey is the topographical department of the War Office, and its maps are engraved partly for strategic purposes; but such minutiæ as I allude to are needless in ordinary maps.

For roads, parish boundaries, railways, &c., the chief, but it is no insuperable difficulty, consists in inserting quadrats which are made

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"height to paper," in tracing the line of road upon them, and in removing the superfluous metal with the engraver. We all know the advantage of the sub-division of labour; and if the compositor cannot use the graver he may be better occupied, and cheaply enough employ some one who can. I could suggest several other methods for producing roads, &c., but nothing with so many conveniences as that proposed. The quadrats or blanks for such are of three sorts—em and two-em nonpareil, and two-line-em nonpareil, which is pica. Roads occurring, as they may, in every conceivable direction, cannot be cast as such. It is easy to make them as proposed, and, after being used, to store them up for future occasion. They have this advantage, too, interlocking with the surrounding types, they retain them, and are retained in position, and prevent the possibility of shifting.

This then is all I need say about the mechanical part of the contrivance; the question for your Society is its approval or its rejection of it, its improvement, and application.

Consider the present mode of producing maps by engraving on copperplate, how wearisome and laborious, how costly in consequence, how evanescent when printed from; true, they can be electrotyped—they are electrotyped; acres of such plates are made at the Ordnance office in Southampton, yet, with all the pecuniary advantages of a Government establishment, annual grants by parliament, honours and emolument to the heads of the staff, with what results? the sale of maps in a year scarcely equals the numbers of a second-rate newspaper in a day, because of the price of them. And here I would urge on the compositor not to be detered by any one's assurance that maps could not be made by moveable types; I take some credit to myself for disregarding all my lifetime that paltry obstacle to all improvement "it cannot be done." You know time was when stereotyping could be done only by plaster-of-Paris, hours were consumed in the operation. I introduced the paper process in 1843 or 1844, and now you have the *Times*, the *Scotsman*, and other papers stereotyped thus every day, in twenty minutes, and the metal of to-day's plates melted down for to-morrow's. Time was when type-casting could be done only by hand. I introduced machine-casting in 1846; it has been much improved, but continued ever since. Look at the price and the quality of types now.

Before a committee of the House of Commons, when the printing of the penny postage label was inquired into, it was affirmed that copperplate engraving could not be equalled by letterpress; now, the only postage label that is not printed typographically is the penny one, and it happens to be the only one of any denomination that can be forged.

It was said to be impossible to print bank notes by letterpress, certainly a severe ordeal to put letterpress to; but, honoured by the managers of the Bank of England with instructions to make the attempt, I succeeded, and engraved all their notes and cheques; 30,000 a day, the smallest denomination of which is L.5, have been printed by letterpress ever since, and cheques by millions and millions perpetually. The numbers could not be printed even from steel plates without a battalion of engravers as formerly; now, they do not keep one.

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Many of the documents for the national debt are done in the same manner. All the bank note plates, the rupee notes for the Government of India, I made in the same way, and shall it be deemed a hopeless task to do maps typographically? certainly not: by this first experiment you see what *can* be done, need you doubt what farther may be accomplished? only make it worth one's while and any map could be reproduced by letterpress. The real question is not "can it be done?" but "is it worth while doing it?" can you dispose of maps to a paying extent? I would undertake even now to execute, in this style, index maps of the Ordnance Survey at a third of the cost, and in a third of the time now occupied.

It was only the other day that the Ordnance Survey maps for England were said to be completed, after upwards of eighty years of labour expended upon them; the engraving and publication of the Scotch maps is shamefully in arrears; at the present rate of progress they will not likely appear in the lifetime of the youngest of us. Four and a half centuries have vanished since printing was invented, still, we make improvements in printing; thirty years hence our children's children may reap the seed we cast abroad to-night in the suggestion offered you, we cannot predicate the future, but *may* hope, may *conjecture* from analogy.

Thirty years ago your newspapers cost 500 per cent. more than they do now, and could scarcely be cheaper than then but for the improvements spoken of in typefounding, in stereotyping, in electrotyping, and machine printing, besides in the modification of the paper duty, the stamp duty, and the tax on advertisements. Surely this is encouragement to young compositors to enter on such an untrodden path as is indicated; we know not whither it may lead, it cannot lead to evil; of this they may be assured, by perseverance in it, they will leave the world somewhat better than they find it. There is no lack of talent in the land. I have no sympathy with the delusive clamour for "technical education" as though want of *that* were the sole or even approximately the chief reason why, in many of our manufactures, we are beaten by foreigners, falling off in quality and our best workmen suffer enforced idleness. I speak from years of personal experience in Prussia and in France, and *know* that anything wanted to be made, unless perhaps it be in some work of taste or in some fanciful design or harmonious blending of colours, we are not to be approached for trustworthy, substantiality, and reliable accuracy, if the essentials be only paid for: the good enough system of working, by ourselves or by others, if we encourage it, the flimsy and the fantastical, provided they be what is called cheap, must overwhelm us in time unless, going to the root of the evil, technical education in the science of society be extended to our *rulers*, and the mistaken legislation which has led to our decline, be upset, to avert our degradation from an envied, a proud supremacy.

I have endeavoured to diversify the dry details of a simple mechanical operation, and to accommodate my remarks so as to interest the predilections and meet the liking for variety in a mixed assembly; with such a theme one could barely expect to be entertaining. However, I hope to have made myself understood by compositors if there be any present: if

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not, I shall gladly be more explicit in private. Here is the first step taken in what I believe to be a workable and promising business novelty for printers.

I have little fear but that it will eventuate in some enterprising publishers adopting it, and in our being supplied with good legible maps at encouragingly reasonable prices. The first to adopt may not be foremost to establish a new branch of trade; prudence, intelligence, and sufficient means to prosecute it are essentials to success in this as in every other commercial enterprise.

The education movement; the convenience and advantage of a newspaper insertion of a portion of a map of the district where an interesting occurrence has taken place; the new phase of topographical information which Telegraphy is developing at home and abroad, along with other adaptations which must occur to yourselves, are sufficient stimulus to perseverance in perfecting a contrivance which I respectfully offer to the consideration of the Society where my earliest lessons in the duties of self-reliance were acquired.

Allow me to thank you for a courteous and indulgent hearing.

After a few remarks by the President and Professor Jenkin, the paper was referred to Dr A. K. Johnston, Mr T. Nelson, and Mr A. Fraser.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 909–910. Presented by the Society.
2. Engineering, Nos. 225, 226. Presented by the Proprietors.
3. Scientific Opinion, Vol. III. Nos. 77, 78. Presented by the Proprietors.
4. Proceedings of the Institute of Mechanical Engineers, Jan. 1870. Presented by the Institute.
5. Proceedings of the Royal Society, No. 118. Presented by the Society.
6. Report on the Tides and Currents in New York Harbour. By Henry Mitchell, Chief of Physical Hydrography. Presented by Mr Mitchell.
7. Railway Economy. By M. Le Chatelier. Translated by Lewis D. B. Gordon, F.R.S.E. Presented by Mr Gordon.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentleman was admitted as an Ordinary Fellow:—

William Marshall, coal merchant, 132 Princes Street.

Twelfth Meeting—11*th July* 1870.—John Paterson, Esq. C.E., Vice-President, in the Chair.

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The following Communications were made :—

1. Answers by Committee on Professor Jenkin's Paper on Braced Arches, to Mr Sang's objection—Professor Smyth, Convener—was read, and after a few remarks by Professor Jenkin, Mr Sang, and Mr A. D. Stewart, was adopted.

2. Report of Committee on Mr P. Stevenson's Atmometro-Hygrometer—Mr J. Nicol, Convener.

3. Report of Committee on Mr John Love's New Planisphere—Dr Ferguson, Convener.

4. Report of Committee on Professor Smyth's Equal Surface Projection for Maps of the World—Professor Jenkin, Convener.

5. Report of Committee on Dr Thomas Cowan's paper on Channel Railways—Mr A. D. Stewart, Convener.

6. Report of Committee on Mr Aytoun's Method of Warming and Ventilating Buildings—Mr Gowans, Convener.

7. Report of Committee on Mr Heriot Currie's Mode of Collecting Bilge Water—Mr D. Stevenson, Convener.

8. Report of Committee on Mr Noble's Safety Apparatus for Coupling Railway Waggons—Mr Stewart, Convener.

9. Report of Committee on Mr J. L. Watson's Rain-Gauge—Mr Romanes, Convener.

10. Report of Committee on Mr G. Pratt Boyd's Improvements in Hydraulic Gas Mains—Mr J. Reid, Convener.

11. Report of Committee on Mr Skirving's Typographical Maps—Mr A. Fraser, Convener—were all read and adopted, with the exception of the Report on Mr Aytoun's Method of Warming and Ventilating Buildings, which had not been sent in.

12. Description of Embossed Music for the Blind. Invented by J. St Clair, Teacher of Music, 13 Frederick Street, was read, and Specimens of the Embossed Music exhibited. After a few remarks by the Secretary, the paper was referred to Messrs A. Leslie, W. Lees, and J. Reid.

13. On the Distillation of Gas from Coal in Short-time Charges as compared with Long-time Charges. By Stevenson Macadam, Ph.D., was read, and after remarks by Messrs Sang, Bow, and Marshall, the communication was referred to Messrs Watson, Reid, and Bow.

The following Donations were laid on the table, and thanks returned to the Donors :—

1. Journal of the Society of Arts, Nos. 911, 917. Presented by the Society.

2. Engineering, Nos. 227, 233. Presented by the Proprietors.

3. Scientific Opinion, Vol. III. Nos. 79, 85. Presented by the Proprietors.

4. Transactions of the Institute of Mechanical Engineers, Jan. 1870. Presented by the Institute.

5. Proceedings of the Royal Society, No. 119. Presented by the Society.

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6. Canadian Journal, Vol. XII. No. 5. Presented by the Canadian Institute.

7. The Artizan, Vol. IV. Nos. 5, 6. Presented by the Proprietors.

8. Memoirs of the Geological Survey of India.

9. Palæontologica Medica. Presented by His Excellency The Governor General of India.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed,

II. The following Gentlemen were admitted as Ordinary Fellows :—

1. James Steel, 103 St Vincent Street, Glasgow.
2. William Mackenzie, gas manager, Dunfermline.
3. Rev. James N. Miller, 2 Upper Gilmore Place.

III. The following gentlemen were appointed to award the Prizes for Session 1869–70, viz.—

Messrs John K. Watson, *V.P.*
Thomas Ivory, *V.P.*
J. J. Lundy.
William Firth.
Alexander Fraser.
James Gowans.
James Johnstone.
William Lees.
John Milne.
A. D. Stewart.
Alexander Reid, and
Dr. Ferguson.

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APPENDIX (G.)

LIST OF PRIZE SUBJECTS FOR SESSION 1870-71.

THE ROYAL SCOTTISH SOCIETY OF ARTS proposes to award prizes of different values, of Thirty Sovereigns, and under, in Gold or Silver Medals, Silver Plate, or Money, for approved Communications, *whether previously published or patented, or not,* submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the *Mechanical* and *Chemical* Arts in general, and in their relation to the Fine Arts, and also to means by which the *Natural Productions* of the Country may be made more available. The Society suggests the following as a few of the many subjects that may be attended to, viz.:—

I. INVENTIONS, DISCOVERIES, or IMPROVEMENTS in the Useful Arts.

1. *Mechanical Arts.*

INVENTIONS or IMPROVEMENTS in applying the Motive Power of Men and Animals,—in Wind and Water Prime Movers,—in Steam and other Heat Engines, including Gas Engines,—in Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines,—in Cotton and other Textile Manufacturing Mills,—in Ship-building in Wood, Iron, and Steel,—in Lighthouses,—in Marine Propellers,—in Railways, Plant and Signals,—in Electric Apparatus,—in Electro-Magnetic Motive Power,—in Electric and other Telegraphic Apparatus, Sub-Marine and Aërial,—in Photographic Apparatus,—in Fire-Proof Buildings,—in Water Supply,—in Paving,—Sewerage,—in Economical Appliances for increasing the Sanitary condition of Towns,—in Smoke Consumption and Extinguishing Fires,—in Gas-Works,—

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in Canals and Inland Navigation, including the application of Steam Power to Canal Traffic,—Canal Locks, Inclines, and Lifts,—Application of Hydraulic Power for Lifts for Domestic Use,—for Cranes,—Printing Presses,—Organ-Blowing, and other similar purposes, where small Propelling Power is required,—Labour-saving Machines for working in Wood,—in Tools, Implements, and Apparatus for the various Trades,—in Sewing Machines,—in Bricks, Encaustic Tiles, Cements and Mortars,—in Printing Machines, Cases, and Rollers,—in Stereotyping,—in Cranes,—in the Machinery for Collieries,—in preserving Timber and Metals in Marine Works,—in Optical Apparatus,—in Manufacture of Paper,—Experiments on the Effect of Low Temperatures on Metals.

2. *Chemical Arts.*

INVENTION or IMPROVEMENTS in new and useful applications of Gutta Percha and Vulcanised India Rubber, or similar Gums,—in the Economical Extraction of Chemical Principles or Useful Substances, as Paraffine, &c., from Coal,—Porcelain Clay from Granite or Felspar—and Metals generally from their Ores and Oxides,—in Dyes,—in Paints,—in Paper,—in Glass, especially for Lenses,—in methods of rendering the Electric Light available in practice.

3. *Relative to the Fine Arts.*

INVENTIONS or IMPROVEMENTS in Photographic processes, in "Carbon" Printing, and in Methods of Printing Photographs from their Impressions on Steel or Copper Plates, or Lithographic Stones,—in Electrotype processes,—in Die-Sinking,—in methods of illustrating Books, to be printed with the letterpress,—in Paper-Hangings,—in Articles of Porcelain, Common Clay, or Metal,—in Glass-Staining,—in Engraving on Stone,—in Chromo-Lithography,—in "Nature" Printing.

4. *Natural Productions.*

DISCOVERY of Plumbago Mines,—Whetstones,—of Woods suitable for Engraving.

II. EXPERIMENTS applicable to the Useful Arts.

III. COMMUNICATIONS of Processes in the Useful Arts practised in this or other Countries, but not generally known.

IV. PRACTICAL DETAILS of Public or other Undertakings of National importance, already executed, but not previously published;—or valuable suggestions for originating such undertakings.

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The KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts, which shall be primarily submitted to the Society" during the Session.

The HEPBURN BIENNIAL PRIZE, value about £12.

(*If not awarded during Session* 1869–70.)

"For such Inventions or Communications submitted to the Society as shall be approved of by the Society, or by their Prize Committee."

The MAKDOUGALL-BRISBANE BIENNIAL PRIZE, value £10.

(*If not awarded during Session* 1869–70.)

"To the Authors or Inventors of Communications of Merit, which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction."

The REID and AULD PRIZES.

For the First, Second, and Third best Models of "Anything New in the Art of Clock or Watch Making,—by Journeymen or Master Watch and Clock Makers,"—if these should be considered worthy of Prizes, the Year's Interest of the Reid and Auld Bequest, being about SEVEN GUINEAS, divided among them in such proportions as the Prize Committee shall fix, according to merit. To such as deserve it, the Society may add to the amount of the Prize out of its general funds.

GENERAL OBSERVATIONS

AND DIRECTIONS FOR PREPARING AND LODGING COMMUNICATIONS.

The descriptions of the various inventions, &c., must be *full* and *distinct;*—be legibly written on *Foolscap* paper, leaving margins at least one inch and a half broad, on *both sides of each page*, so as to allow of their being bound up in volumes; and, when necessary, be accompanied by *Specimens, Drawings, or Models.* All Drawings to be on *Imperial* Drawing-Paper, unless a larger sheet be requisite. The Drawings to be in *bold* lines, not less than a quarter of an inch broad, or *strongly coloured*, so as to be easily seen at about the distance of thirty feet when hung up in the Hall, and the Letters or Figures of Reference to be at least 1½ inch long. When necessary, smaller and more minutely detailed Drawings should

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accompany the larger ones, for the use of the Committees, having the same letters of reference. Short abstracts must accompany the papers.

The Society shall be at liberty to publish in their Transactions copies or abstracts of all papers submitted to them. All Models, Drawings, &c., for which Prizes are given, shall be held to be the property of the Society; but the Value of the Model, if retained, will be separately allowed for.

Communications, Models, &c., are to be addressed to the SECRETARY, 2 George Street, Edinburgh, Postage or Carriage paid; and should be lodged on *or before 2d January* 1871, in order to insure their being read and reported on during the Session (the ordinary Meetings of which commence in November 1870, and end in April 1871). Communications lodged after the 1st March may not be read or reported on till the following Session.

By order of the Society.

EDWARD SANG, *Secretary.*

EDINBURGH, *April* 1870.

*** *Copies for distribution may be had from the Secretary.*

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APPENDIX (H.)

REPORT

OF

THE COMMITTEE

APPOINTED BY

THE ROYAL SCOTTISH SOCIETY OF ARTS

TO AWARD PRIZES FOR COMMUNICATIONS READ AND EXHIBITED DURING SESSION 1869-70.

Your COMMITTEE having met and carefully considered the various Communications laid before the Society, and reported on during the Session 1869–70, beg to report that they have awarded the following Prizes:—

1. To JAMES MACKENZIE, Manager's Department of the North British Railway Company,—for his "Description of Improvements in Couplings for Railway Wagons,"—read and Mode exhibited, 28th March 1870 (No. 4227).

   The Keith Prize, value Thirty Sovereigns.

2. To FLEEMING JENKIN, F.R.SS. L. & E., Professor of Civil Engineering in the University of Edinburgh,—for his Paper on Braced Arches,—read and Illustrative Drawings and Models exhibited, 13th December 1869 (No. 4212).

   The Hepburn Prize, value Seven Sovereigns.

3. To HERIOT CURRIE, F.R.S.S.A., Chief Engineer of the Northern Light Commissioners' Steamship Pharos,—for his "Description of Improvements in Collecting the Bilge Water in Ships,"—read, and Models and Drawings exhibited, 9th May 1870 (No. 4232).

   The Macdougal Brisbane Prize, value Six Sovereigns.

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4. To STEVENSON MACADAM, Ph.D., F.R.S.E., Lecturer on Chemistry,—for his "Paper and Experiments on the Economic Distillation of Gas from Cannel Coals,"—Paper read 22d November 1869 (No. 4211).

The Society's Silver Medal and Plate, value Five Sovereigns.

5. To THOMAS WILL, Basket-Maker, Edinburgh Asylum for the Blind,—for his "Description of an Instrument for Cutting Willows,"—read, and Instrument exhibited in action, 14th March 1870 (No. 4221).

The Society's Silver Medal and Plate, value Four Sovereigns.

6. To JOHN LOVE, Banker, Greenock,—for his "Description of a New Planisphere for showing the Altitude and Azimuth of the Sun or Star,"—read, and Planisphere exhibited, 25th April 1870 (No. 4226).

The Society's Silver Medal, value Three Sovereigns.

7. To JAMES DAVIE, Printer,—for his "Description of a Mechanical Balloting Apparatus for Parliamentary and Municipal Elections,"—read, and Model exhibited, 10th January 1870 (No. 4214).

The Society's Silver Medal and Plate, value Three Sovereigns.

8. To PETER STEVENSON, Philosophical Instrument Maker,—for his "Description of an Atmometro-Hygrometer,"—read, and Instrument exhibited, 24th January 1870 (No. 4216).

The Society's Silver Medal and Plate, value Three Sovereigns.

9. To JAMES L. WATSON, Executive Engineer, Madhapoor, Punjaub,—for his "Description of a Self-Registering Rain-Gauge,"—read, and Instrument exhibited, 9th May 1870 (No. 4234).

The Society's Honorary Silver Medal.

10. To JAMES KERR, Superintendent, Sheriff Court-House,—for his Paper on Sanitary Improvements,—read 10th January 1870 (No. 4213).

The Society's Honorary Silver Medal.

Your Committee recommend that, while *Thanks* are justly due to all those gentlemen who have sent Communications,

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the *Special Thanks* of the Society be given to the following gentlemen:—

1. To Robert Henry Bow, C.E., F.R.S.E.,—for his Paper on Improvements in Stop-Cocks,—read, and specimen exhibited, 14th March 1870 (No. 4225).

2. To Thomas William Cowan, C.E., Ph.D.,—for his Paper on the Schemes for Communication across the English Channel,—read 25th April 1870 (No. 4230).

3. To Charles Piazzi Smyth, F.R.S.E., Astronomer Royal for Scotland,—for his Paper on Equal Surface Projections for Maps of the World,—read 9th May 1870 (No. 4229).

4. To William Noble, Engineer,—for his Description of a Safety Apparatus for Coupling Railway Wagons,—read, and model exhibited, 9th May 1870 (No. 4233).

5. To George Pratt Boyd, Manager of the Gas Works, Alloa,—for his Paper on Hydraulic Mains for Gas Works,—read, and illustrative drawings and model exhibited, 9th May 1870 (No. 4235).

6. To John Skirving, Letter Press Engraver to the Bank of England,—for his Paper on a Process for Producing Maps Typographically,—read, and specimen exhibited, 9th May 1870 (No. 4236).

Your Committee have to report that the Committee on aper No. 4210, by Mr Thomas Davidson, Optician, having been unable to complete their report, the paper has been continued till next Session, as also that no Report having been returned by the Committee on Mr Aytoun's Paper, No. 4231, on Warming and Ventilation, the consideration of it has been postponed.

All which is humbly reported, in name and by order of the Committee, by

EDWARD SANG,
Sec., Convener ex officio.

Society's Hall, 117 George Street.
20th October 1870.

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APPENDIX (I.)

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1868–69.

I. REVENUE AND EXPENDITURE.

1. GENERAL FUNDS.

Revenue.				Expenditure.			
Arrears of Annual Contributions received	£11	11	0	1. ORDINARY—			
Annual Contributions for Session 1868–69 received	282	9	0	Prizes awarded	£17	10	0
Interest on Account with the Commercial Bank received	1	10	8	Printing and Advertising	40	2	9
Compositions in lieu of Annual Contributions received, £34, 13s., whereof 5 per cent. applicable to Revenue, as recommended by Committee on Accounts	1	14	6	Expenses of the Society's Printed Transactions	63	19	0
				Books for the Library	0	5	0
				Fees to Committees for Reports	4	10	0
				Repairs, Furnishings, &c., for the Hall	13	18	8
				Salaries & Expenses of Collection	108	11	2
				Miscellaneous Payments	9	6	0
					£258	2	7
				2. EXTRAORDINARY—			
				Expense of Arranging and Binding back numbers of the Printed Transactions	22	5	0
				Price of Oak Case for use of Secretary	4	15	0
					£285	2	7
				Excess of Revenue over Expenditure	12	2	7
	£297	5	2		£297	5	2

II. KEITH BEQUEST.

REVENUE.

Dividends from Edinburgh Gas-Light Company's Stock	£15	0	0
Dividends from British Linen Company Bank Stock	13	0	0
Dividends from Royal Bank Stock	19	10	10
Amount	£47	10	10

EXPENDITURE.

Interest on Bank Account	£0	0	7
Excess of Revenue	£47	10	3

III. REID AND AULD BEQUEST.

REVENUE.

Dividends from National Bank Stock	£14	0	0
Interest on Sums in Bank	0	2	0
Amount	£14	2	0

IV. BRISBANE BIENNIAL PRIZE FUND.

REVENUE.

Dividends from Government Stock	£5	2	8
Interest on Bank Account	0	1	10
Amount	£5	4	6

V. HEPBURN PRIZE FUND.

REVENUE.

Dividends from Caledonian Railway Company Stock	£7	5	4
Interest on Bank Account	0	0	8
Amount	£7	6	

No Special Prizes were awarded in Session 1868–69.

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I. REVENUE AND EXPENDITURE—continued.

VI. BUILDING FUND.

REVENUE.

Rents drawn from Letting of Hall			£123 5 10

EXPENDITURE.

Payments on account of Hall, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, &c., and Hall Keeper's Salary	£97 12 10¾			
Interest at 4 per cent. on Loans towards purchase of premises	£27 6 3			
Interest on Bank Account	0 1 1			
		27 7 4		
			125 0 2¾	
Excess of Expenditure over Revenue			£1 14 4¼	

II. FUNDS OF THE SOCIETY.

As at 15th November 1869, *per Report of Committee on Books and Accounts.*

I. GENERAL FUND.

1. Price of Hall in George Street and Furnishings, exclusive of the additional Premises purchased at Whitsunday 1863, and stated under "Building Fund," below			£1820 3 11	
2. Arrears of Annual Contributions			24 3 0	
3. Balance in Bank			71 16 0	
			£1916 2 11	
Less—1. Balance due to Treasurer	£3 9 10			
2. Balance of Subscriptions for Expenses of Conference on Technical Education unexpended	9 5 2			
		12 15 0		
AMOUNT			£1903 7 11	

II. KEITH BEQUEST.

1. Six Shares of the Edinburgh Gas-Light Company, at £52, 15s.,	£316 10 0		
2. £100 Stock of the British Linen Company's Bank	268 0 0		
3. £250 Stock of the Royal Bank, at £173	432 10 0		
4. Balance in Commercial Bank	32 14 4		
	£1049 14 4		
Less—Balance due to Treasurer	1 1 9		
AMOUNT		1048 12 7	

III. REID AND AULD BEQUEST.

1. £100 National Bank Stock	£274 0 0		
2. Balance in Bank	155 11 5		
3. Balance due by the Treasurer	0 1 10		
AMOUNT		429 13 3	

IV. BRISBANE PRIZE FUND.

1. £175, 3 per cent. Consols, at 93½	£163 12 6		
2. Balance in Bank	11 14 11		
AMOUNT		175 7 5	

V. HEPBURN PRIZE FUND.

1. £100 Stock of the Scottish Central Railway Company	£141 15 0		
2. One £10 Share, No. 2, 4½ per cent. Preference Stock of do.	9 13 0		
3. Balance in Bank	10 1 5		
AMOUNT		161 9 5	

VI. BUILDING FUND.

(For the purchase of premises adjoining and under Society's Hall.)

Price of Premises and Furnishings, &c.	£891 16 4		
Less—Loans repayable	700 0 0		
AMOUNT		191 16 4	
Total value of Property and Funds under charge of the Society as at 15th November 1869		£3910 6 11	

JOHN SCOTT MONCRIEFF, *Treasurer.*

EDINBURGH, 14*th April* 1870.

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APPENDIX (J.)

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS,

AS AT 1st NOVEMBER 1870.

THE QUEEN, PATRONESS.

OFFICE-BEARERS FOR SESSION 1869–70.

President, ——— R. W. THOMSON, C.E., F.R.S.E., 3 Moray Place.

Vice-Presidents, ——— JOHN KIPPEN WATSON, F.R.S.E., 25 Waterloo Place.
THOMAS IVORY, Advocate, 23 Walker Street.

Secretary, ——— EDWARD SANG, F.R.S.E., 2 George Street.

Treasurer, ——— JOHN SCOTT MONCRIEFF, C.A., Chambers, 26 Frederick Street.

Editor of Transactions, ——— STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., &c., Surgeons' Hall, Nicolson Street.

Curator of Museum, ——— ALEXANDER JAMIESON, 71 Adam Square.

Medalist, ——— ALEXANDER KIRKWOOD, 9 St James' Square.

Officer and Collector, ——— JOHN BELL, 117 George Street.

Councillors.

*ALLAN D. STEWART, C.E., 12 Castle Street.

*WILLIAM FIRTH, Rose Villa, Viewforth.

*JAMES GOWANS, Rockville, Napier Park.

*ALEXANDER FRASER, Old Fishmarket Close.

ROBERT H. BOW, C.E., F.R.S.E., 7 South Gray Street.

JOHN PATERSON, C.E., 27 St Hope Terrace.

ADAM MOSSMAN, Jeweller, 30 Princes Street.

CHARLES PEARSON, C.A., 128 George Street.

A. BREBNER, C.E., 84 George Street.

GEORGE HARRISON, Merchant, 12 Blackford Road.

CHARLES MACPHERSON, C.E., 10 Glengyle Terrace.

Professor FLEEMING JENKIN, F.R.SS L. & E., 5 Fettes Row.

The four Ordinary Councillors marked * retire by rotation,

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LIST OF THE ORDINARY FELLOWS,

AS AT 1st NOVEMBER 1870.

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1822.*ABERCORN, The Most Noble James, Marquis of, K.G., &c., Chesterfield House, London.
1850.*Adie, A. J., F.R.S.E., C.E., 5 St Andrew Square.
1860. Adie, Richard, optician, 50 Princes Street.
1863. Aitchieson, Thos. Stodart, 45 Lauriston Place.
1860. Aitchison, William John, 11 Buckingham Terrace.
1865. Aitken, Henry, manager, Darroch Coal and Iron Works, Falkirk.
1868. Aitken, William, accoucheur, Eastwood, Carnwath.
1860. Alder, Henry, gas-meter maker, 32 Grange Road.
1851.*Alexander, William, M.E., 23 India Street, Glasgow.
1841.*Anderson, Charles W., merchant, 2 Mansion House Road.
1850.*Anderson, Thos., M.D., F.R.S.E., Professor of Chemistry, 15 Shuttle Street, Glasgow.
1863. Andrews, James, C.E., 84 George St.
1861. Archer, Thos. C., Director of the Museum of Science and Art.
1868. Archibald, John, M.D., Biggar.
1826.*Aytoun, Robert, W.S., 3 Fettes Row.

1867. Baillie, John M., C.A., 15 Northumberland Street.
1856. Bain, Wm., engineer, Lochrin.
1836.*Ballantyne, J., of Holylee, Innerleithen.
1869. Baxter, Sir David, Bart. of Kilmaron, 5 Moray Place.
1865. Beattie, Adam, builder, 3 Chalmers Street.
1861. Beith, Donald, W.S., 43 Castle Street.
1850.*Bell, Alexander Melville, teacher of elocution, 18 Harrington Square, London.
1859.*Bell, Andrew Beatson, advocate, Court-House, Cupar-Fife.
1857. Bell, B., surgeon, 8 Shandwick Place.
1858. Bell, James, railway engineer, 28 Brighton Place, Portobello.
1867. Bell, Robert, coal-merchant, Wishaw.
1861. Bell, William, stockbroker, 8 North St David Street.
1867. Bennet, James Henry, engineer, 7 Vanburgh Place, Leith.
1861. Bernard, James A., 4 Manor Place.
1847.*Bernard, Thomas, brewer, 8 Leopold Place.
1861. Bethune, Norman, M.D.
1859. Black, Adam, publisher, 38 Drummond Place.
1865. Black, Rev. Arch. Pollok, The Manse, Bow Road, London.
1868. Blair, Rev. Rob. Hugh, rector of St Michaels, Worcester.
1863.*Blanshard, George, wholesale druggist, 7 Carlton Terrace.
1849.*Bouch, Thomas, C.E., 78 George Street.
1853.*Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street.
1863. Bowie, Andrew F., 4 Pilrig Street.
1870. Boyd, George Pratt, Gas Engineer, Alloa.
1868. Boyd, James L., S.S.C., 1 Regent Terrace.
1848.*Brebner, A., engineer, 84 George Street.
1869. Brodie, David, M.D., Columbia Lodge Liberton.
1861. Brown, D. R., manufacturing chemist, 1 St John Street.
1864. Brown, Geo. Bruce, architect, 26 Elder Street.
1839.*Brown, Thos., architect, 19 St Andrew Square.
1868.*Bruce, C., banker, 2 Glenfinlas Street.
1850.*Bruce, George Cadell, C.E., 21 Castle Street.
1833.*Bryce, David, architect, 131 George Street.
1851.*Bryden, J., bell-hanger, 55 George Street.
1857. Bryson, J. M., optician, 60 Princes Street.
1860. Bryson, Robt., watchmaker, 66 Princes Street.
1822.*BUCCLEUCH and QUEENSBERRY, His Grace Walter, Duke of, K.G., A.M., F.R.SS. L. & E., Dalkeith Palace.
1835.*Burn, William, architect, 6 Stratton Street, Piccadilly, London.

1851. Cadell, Henry, M.E., Grange, Bo'ness.

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1846.*Callender, John A., merchant India Buildings.
1859.*Cameron, P., contractor, 25 George Square.
1834.*Campbell, Alex., brewer, 6 Charlotte Square.
1862. Carlisle, James, engineer, 5 Hope Park Crescent.
1865.*Carmichael, Peter, Den's Works, Dundee.
1858. Carphin, James R., C.A., 26 Northumberland Street.
1840.*Carstairs, Drysdale, merchant, Liverpool.
1864. Carter, Frederick Hayne, C.A., 8 Eton Terrace.
1867.*Cay, Wm. Dyce, C.E., 7 Blackford Road.
1864. Chalmers, T., Longcroft, Linlithgow.
1867. Chambers, William, of Glenormiston, 13 Chester Street.
1860. Charnock, Richard Stephen, 8 Gray's Inn Square, London.
1857. Chaumont, F. D., M.D., 1st Battalion Rifle Brigade, Woolston, Southampton.
1861. Chisholm, David, actuary, 9 Rill Bank Terrace.
1856.*Chisholm, John Knox, dentist, 15 Duke Street.
1860. Christie, John, 18 Mayfield Terrace.
1866. Clapperton, W. R., merchant, 59 Princes Street.
1862. Copland, Harry Y. D., 27 Stafford St.
1847.*Cousin, David, city-architect, City Chambers.
1869. Cousin, George, architect, 5 Bruntsfield Terrace.
1836.*Cowan, Charles, paper-manufacturer, Valleyfield, Penicuik.
1864. Cox, John, glue manufacturer, Gorgie House, Murrayfield.
1859. Cox, Robert, W.S., 25 Rutland Street.
1863. Craig, David, paper-maker, Portobello.
1866.*Craig, James, distiller, 33 Manor Pl.
1865.*Craig, Robert, paper-maker, Craigesk, Dalkeith.
1832.*Craig, Sir William Gibson, of Riccarton, Bart, F.R.S.E., Hermiston.
1860. Cuningham, Alex., secretary to the Commissioners for Northern Lights, 84 George Street.
1851.*Cunningham, George, C.E., 2 Ainslie Place.
1857. Cunningham, James, W.S., F.R.S.E., 50 Queen Street.
1863. Currie, Heriot, engineer, 4 Auburn Place, North Leith.
1867. Cusiter, G. F., gas-engineer, Dalkeith.

1868. Davidson, James, M.E., Newbattle.
1869. Davies, William Henry, carver and gilder, 89 George Street.
1850. Davison, Samuel D., Boswell House Wardie.
1865. Day, St John Vincent, C.E., 166 Buchanan Street, Glasgow.
1867. Deans, Peter Dods, Mount Charles, Bath Street, Portobello.
1865. Deas, James, C.E., Glasgow.
1844.*Dickson, J. Jobson, C.A., 13 Clarendon Crescent.
1850. Dickson, John, junior, gunmaker, 63 Princes Street.
1866. Dods, G., assessor of railways, 5 Gayfield Square.
1860. Douglas, F. Brown, 21 Moray Place.
1859.*Dryborough, Rich., cooper, 4 Hermitage Place, Leith.
1866. Duncan, Thos., 16 North Mansion House Road.
1866. Dunn, John H., 3 Lord Russell Place
1844.*Dunn, Thos., optician, 7 Buccleuch Place.

1853. Elliot, Professor James, Goldielands, Hawick.
1839.*Ellis, T., upholsterer, 21 George IV Bridge.
1864. Ellis, W. M., merchant, 8 Wellington Street, Portobello.
1857. Esson, Geo. A., Accountant in Bankruptcy, 10 Great King Street.

1850.*Falshaw, James, C.E., 26 Castle Street.
1864. Ferguson, John, engraver, North St Andrew Street.
1857. Ferguson, R. M., Ph.D., F.R.S.E., 12 Moray Place.
1850.*Ferguson, William Black, C.E., 129 Union Street, Aberdeen.
1869. Fidler, Thomas Claxton, C.E., 9 Victoria Chambers, London.
1864. Field, Thomas, slate-merchant, 27 Frederick Street.
1860. Firth, William, secy., N. B. Rubber Co., Castle Mills.
1840.*Fleming, Alex., W.S., 20 Lynedoch Place.
1861. Fleming, A. B., chemical manufacturer, 12 Eton Terrace.
1865. Flockhart, Wm., chemist, 52 North Bridge.
1869. Forman, John, 51 Great King Street.
1869. Forrest, Thomas, junior, ironmonger 29 South Clerk Street.
1840.*Forrester, John, W.S., 8 Drummond Place.
1850.*Fraser, Alexander, printer, Old Fish-market.
1847.*Fullarton, John A., publisher, 12 Claremont Street.

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1869. Galt, Robert, jun., coal-master, 20 Buchanan Street, Glasgow.
1856.*Geddes, A. C., C.E.
1856.*Geddes, G. H., M.E., 9 Lynedoch Place.
1842.*Gillespie, John, W.S., 53 Northumberland Street.
1854.*Girdwood, Robert, merchant, Tanfield.
1850.*Glennie, Geo., C.E., 43 Upper Thames Street, London.
1859. Gordon, Alexander, colliery manager, Thorniebank, Dalkeith.
1861. Gowans, Alex., 3 Viewforth Road.
1850.*Gowans, James, builder, Rockville, Napier Road.
1865. Gray, Alex., ironmonger, 85 George Street.
1832.*Gray, James, ironmonger, 39 Gt. King Street.
1861. Gray, Robert, gas-engineer, 15 Carnarvon Street, Glasgow.
1860. Gray, Rev. W. H., M.A., minister of Lady Yester's, 5 Regent Terrace.
1866. Greene, R. Massy, C.E., New Dock Works, Leith.
1850. Gregory, Thos. Currie, C.E., Glasgow.
1858. Greig, David, engineer, Greenhill Park.
1835.*Groat, A. G., of Newhall, 12 Hart Street.

1855. Hallard, Fredk., F.R.S.E. Sheriff-substitute of Edinburgh, 7 Whitehouse Terrace.
1833.*Hamilton, Alex., W.S., LL.B., F.R.S.E., 35 Queen Street.
1860. Hardie, Walter, printer, 2 William Street.
1866. Harrison, G., merchant, 12 Blackford Road.
1855. Hart, Wm., phil.-instrument maker, Short's Observatory.
1870. Hartnell, Wilson, engineer, 65 York Place.
1840.*Harvey, Sir George, P.R.S.A., F.R.S.E., 21 Regent Terrace.
1853.*Hay, Geo. W., of Whiterigs, F.R.S.E., Devon Lodge, Starcross, Devon.
1835.*Hay, James, F.R.S.E., merchant, Leith.
1867. Hay, William, architect, 17 Hill Street.
1863. Henderson, Robert, builder, 21 West Maitland Street.
1856. Henry, Alex., gunmaker, 12 South St Andrew Street.
1836.*Hepburn, J. Stewart, of Colquhalzie, Auchterarder.
1839.*Hill, Laurence, jun., C.E., Inch Works, Port-Glasgow.
1863. Hogue, D. W., M.D., dentist, 65 Queen Street.
1864.*Hood, Archibald, M.E., Whitehill Colliery, Lasswade.

1870. Horne, Robert Reston, Kenmuirhill Colliery, Toll Cross, Glasgow.
1868. Horsburgh, John, photographer, 131 Princes Street.
1834.*Horsburgh, Robt., Southbank House, Penicuik.
1863. Hossack, B. H., teacher, 33 Charlotte Square.
1838.*Hunter, Richard, H.E.I.C.S., 10 Ainslie Place.
1859. Hunter, Robert, advocate, Sheriff of Buteshire, 67 Northumberland St.

1857. Imlach, Francis B., F.R.C.S.E., 48 Queen Street.
1859. Ivory, Thomas, advocate, 23 Walker Street, *Vice-President.*

1854. Jackson, Ed. James, B.A. Oxon., 6 Coates Crescent.
1850.*Jardine, Wm. Alex., C.E., 19 Queen Street.
1848.*Jefferiss, Robert R., M.D., Dalkeith.
1869. Jenkin, Fleeming, F.R.SS. L. & E. Professor of Civil Engineering, 3 Fettes Row.
1858. Johnston, Adam, solicitor, 1 Register Place.
1840.*Johnston, Alex. K., LL.D., F.R.S.E. geographer to the Queen, 4 St Andrew Square.
1867. Johnstone, James, of Larchhill, 9 Royal Terrace.
1850.*Johnstone, William, C.E., 14 Bridge Street, Glasgow.
1850.*Jopp, Charles, C.E., 3 Royal Terrace.

1857. Kay, John Zuill, Phœnix Iron Works, Glasgow.
1839.*Kennedy, Wm., W.S., 59 Northumberland Street.
1867. Kennedy, W. Wemyss, machinist, 111 Princes Street.
1865. Kerr, John F., gas-engineer, Copiapo, Chili.
1836.*Kirkwood, Alex., *Medalist*, 9 St James' Square.
1857. Kirkwood, Wm. B., accountant, 6 St Andrew Square.

1861. L'Amy, Sylvester.
1857. Landale, And., iron-master, Lochgelly.
1852.*Landale, David, M.E., 6 Forth Street.
1868. Landale, James, M.E., 6 Forth Street.
1836.*Lawson, Charles, of Borthwick Hall, 35 George Square.
1858. Lawson, Charles, jun., seedsman, 34 George Square.
1859. Lawson, George Stodart, 35 George Square.
1836.*Lees, George, LL.D., St Andrews.

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1850.*Lees, Henry, accountant, 6 York Place.
1856. Lees, William, A.M., Linkvale, Viewforth.
1866.*Leslie, Alexander, C.E., 39 Northumberland Street.
1850.*Leslie, James, C.E., 72 George Street.
1850.*Lessels, John, architect, 21 Heriot Row.
1863. Lockhart, James, engineer, 27 Elmbank Place, Glasgow.
1852. Lorimer, James, C.E., 99 George St.
1862. Lundy, J. J., Assembly Street, Leith.

1856.*Macadam, Stevenson, Ph.D., F.R.S.E., *Editor of Trans.*, Surgeons' Hall.
1839.*Macbrair, D. J., S.S.C., 12 Gt. King Street.
1868. MacCallum, James, C.E., 35 Lorraine Place, Newcastle-on-Tyne.
1870. M'Connell, Frederick, of Robgill, Kirtle Lodge, Trinity.
1850.*Macdonald, D., cotton-spinner, Aberdeen.
1866. Macdougall, William, C.E., 17 Buckingham Terrace.
1868. Macfarlane, Walter, Saracen Foundry, Glasgow.
1861. M'Glashan, Stewart, sculptor Canonmills Bridge.
1850.*Mackay, John, pharmaceutical chemist, 121 George Street.
1861. Mackenzie, Charles, bookseller, 40 Greenhill Gardens.
1867. M'Kenzie, James, manager, Scottish Vulcanite Co., Viewforth.
1869. Mackenzie, James, chemist, 49 George IV. Bridge.
1870. Mackenzie, William, Gas Manager, Dunfermline.
1839.*Maclagan, Douglas, M.D., F.R.S.E., Prof. of Medical Jurisprudence, 28 Heriot Row.
1870. Maclagan, John Thomson, manufacturing chemist, 7 James' Place, Leith.
1863.*Maclagan, Peter, of Pumpherston, M.P., Mid-Calder.
1867.*Maclagan, R. Craig, M.D., 5 Coates Crescent.
1869. Maclaren, David, 34 Buckingham Ter.
1866. M'Laren, Duncan, M.P., Newington House.
1858. M'Lean, Hector Frederick, W.S., 3 Hill Street.
1869. M'Leod, William Bowman, dentist, 43 George Square.
1861. M'Nab, John, Inglis Green, Slateford.
1861. Macnair, John, 33 Moray Place.
1867. Macnaughton, Alexander, S.S.C., 18 Young Street.
1863. Macnie, John, gas-engineer, Lecky Road, Londonderry.
1861. Macpherson, Chas., C.E., 10 Glengyle Terrace.
1850.*Marjoribanks, William, merchant Warriston House.
1867. Marshall, David, engineer, Madeira Street, North Leith.
1843.*Marshall, G. H., jeweller, 3 Heriot Row.
1858. Marshall, Thomas R., goldsmith, East Castle Road. Merchiston.
1860. Marshall, William, engineer, Madeira Street, North Leith.
1870. Marshall, William, coal-merchant, 14 South Charlotte Street.
1869. Mason, Samuel Lack, general manager, North British Railway, Pentland Villa, West Coates.
1860. Matheson, Robert, architect 25 Abercromby Place.
1867. Maule, Thos. H., LL.D., Eildon House, Melrose.
1850.*Mein, Archibald, dentist, 94 George Street.
1861. Meldrum, Edward, of Dechmont, Bathgate.
1860. Melville, F. Suther, assistant-clerk of Session, 16 Broughton Place.
1850.*Melville, Jas. M., W.S., 110 George Street.
1863. Menzies, Duncan, architect, 13 Young Street.
1865. Menzies, Wm. John, W.S., Canaan Cottage.
1857.*Millar, John, merchant, 13 York Place.
1870. Miller, Rev. James N., 2 Upper Gilmore Place.
1829.*Miller, Jn., of Leithen, C.E., F.R.S.E., M.P., 2 Melville Crescent.
1868. Miller, Richard R., Upper Hermitage.
1861. Millidge, J.J., goldsmith, 28 Princes Street.
1859.*Miln, James, of Murie.
1865. Milne, James, engineer, 16 Windsor Terrace, Glasgow.
1848.*Milne, John Kolbe, dressing-case maker 126 Princes Street.
1859.*Milne, John, 44 Albany Street.
1850.*Moffatt, W. L., architect, 23 Minto Street.
1838.*Moncrieff, John Scott, C.A., *Treasurer*, 26 Frederick Street.
1865. Moore, Wm., M.E., 49 West George Street, Glasgow.
1863. More, Jas. L., writer, 25 Scotland Street.
1854. Morrison, Adam, S.S.C., 45 York Place.
1858. Morrison, J. D., dentist, 27 Grange Road.

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1838.*Morton, Hugh, engineer, Victoria Dock, Leith.
1855.*Mossman, Adam, jeweller, 30 Princes Street
1858. Mudie, D. C., Panmure Foundry, North Back of Canongate.
1857. Muir, John, brewer, 5 Pilrig Street.
1857. Muir, R. G., brewer, 9 Bellevue Ter.
1869. Muir, William Hamilton, of Shawhill, 18 Picardy Place.
1866. Muir, W. J. Cockburn, C.E., 9 Victoria Chambers, Westminster, London.
1861. Muirhead, And., painter, 32 Frederick Street.
1868. Murray, John, 48 Castle Street.

1838.*Nachot, W. H., Ph.D., teacher of German, 73 Queen Street.
1868. Nairn, Andrew, 21 Albany Street, Leith.
1860. Nelson, Thomas, publisher, Hope Park.
1858. Nicol, John, chemist, 4 Dundas St.

1850.*Ogilvie, A., merchant, Old Liston, Ratho.
1866. Oliver, John S., merchant, 8 Greenhill Park.
1860. Ower, C., engineer, Craigie Ter., Dundee.

1865. Park, Ebenezer, engineer, 18 Greenside Lane.
1863. Park, James Dove, engineer, 18 Greenside Lane.
1866. Parkes, S. H., 5 St Mary's Road, Birmingham.
1844.*Paterson, John, C.E., 27 Hope Terrace.
1846.*Paterson, W., Scot. Cent. Rail., Perth.
1859. Paterson, Wm., banker, 4 Regent Ter.
1868. Paton, Samuel, teacher, Lamington.
1840.*Pearson, Charles, C.A., 128 George St.
1861. Peebles, D. B., engineer, 18 Viewforth Terrace.
1865.*Peters, A. M., plumber, 13 Dundas St.
1862. Pilkington, F. T., architect, 2 Hill St.
1861. Platt, Leon J., dentist, Stirling.
1868. Potts, R. Collins, 15 Henderson Place, Ferry Road.
1864. Proudfoot, David C., burgh surveyor, 10 Union Street, Leith.

1862. Rainie, Robert, C.A., 6 Clifton Ter.
1850.*Ramsay, Alex., Greenhill Park.
1835.*Ranken, Francis, glass-merchant, 16 Picardy Place.
1842.*Rankine, W. J. Macquorn, F.R.SS. L. and E., Prof. of Civ. Eng., 59 St Vincent Street, Glasgow.
1857. Reid, A., optician, 31 Castle Street.
1860. Reid, John, engineer, Edin. and Leith Gas Co., 2 Queen's Place, Leith.
1848.*Reid, R. L., painter, 2 Blenheim Place.
1843.*Rhind, David, F.R.S.E., architect, 54 Great King Street.
1850.*Richardson, R., merchant, 16 Coates Crescent.
1865. Riddock, Jn., teacher, Neston, Cheshire.
1853. Ritchie, A., watchmaker, 29 Leith St.
1867. Ritchie, David, smith, 14 Lauriston Gardens.
1865. Ritchie, Frederick James, clockmaker, 25 Leith Street.
1862. Ritchie, James, wholesale stationer, 13 Blackett Place.
1866. Ritchie, Jas., watchmaker, 25 Leith Street.
1834.*Ritchie, R., C.E., Assoc. Inst. C.E., 16 Hill Street.
1870. Roberts, George, builder, 1 Grosvenor Street.
1843.*Roberts, W.A., M.D., dentist & surgeon, 30 Queen Street.
1866. Robertson, Andrew, secretary, Scottish Provincial Assurance Company, 5 Howard Place.
1859. Robertson, G., M. Inst. C.E., F.R.S.E. 47 Albany Street.
1855. Robertson, J., druggist, 35 George Street.
1864. Robertson, William, engineer, 16 Madeira Street, Leith.
1857. ROLLO, Right Hon. Lord, Duncrub House, Bridge of Earn.
1868. Romanes, George, C.E., 5 St Andrew Square.
1853.*Rose, J. T., shipbuilder, 3 Oxford Street.
1868. Rowan, Thomas, North Woodside House, Glasgow.
1869. Rowatt, Thomas, lamp-manufacturer, Palmerston Road.
1867. Rowbotham, Rev. Frederick, M.A., 3 Bellevue Place.
1838.*ROXBURGHE, His Grace James H. R., Duke of, K.T., Floors, Kelso.
1866. Russel, John, merchant, 4 Baxter's Pl
1835.*Russell, J. Scott, C.E., F.R.SS. L. & E. Sydenham, London.

1864. Samuel, Peter, merchant, 15 Hanover Street.
1843.*Sanderson, J. H., lapidary, 92 Princes Street.
1867. Sanderson, William, rectifier, Quality Street, Leith.
1869.*Sang, David, 9 Brandon Street.
1828.*Sang, Edward, F.R.S.E., 2 George Street, *Secretary.*
1860. Sang, Edward Elmslie, C.E., 2 George Street.
1843.*Schenck, Frederick, lithographer, 8 South St Andrew Street.
1850.*Scott, Arch., architect, 10 Teviot Row.

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1870. Scott, Robert, Addiewell Chemical Works, West Calder.
1850.*Scrymgeour, Henry, upholsterer, 73 George Street.
1851. Seton, Lt.-Col. R. S., Madras Artillery, 9 Windsor Street.
1843.*Shanks, Thomas, engineer, Johnston, Renfrewshire.
1869. Shaw, P,. contractor, 6 Cambridge St.
1862. Shedden, Thomas, M.A., Arrochar.
1866. Sim, Francis Ranken, glass-merchant, 96 Princes Street.
1863. Sim, William, Edinburgh Colour Works, Leith Walk.
1865. Simpson, George, Bonhar Colliery, Whitburn.
1864. Simpson, James, architect, Daisy Bank, Ferry Road.
1856. Slight, G. H., engineer, North Esk Mill, Dalkeith.
1862. Sligo, A. V. S., 5 Drummond Place.
1854. Small, John, Librarian, University.
1857. Smith, Adam G., C.A., 5 Lennox Street.
1850.*Smith, A., C.E.
1839.*Smith, D., F.R.S.E., manager, North British and Mercantile Insurance Co., 64 Princes Street.
1865. Smith, David, contractor, 61 Brougham Street, Belfast.
1864. Smith, John, C.E.
1865. Smith, John D., carver and gilder, 21 Frederick Street.
1856. Smith, Robt. M., F.R.S.E., merchant, 4 Bellevue Crescent.
1859. Smith, William, lithographer, 43 Northumberland Street.
1855. Smyth, Chas. Piazzi, F.R.SS.L. & E., Astronomer-Royal for Scotland, 15 Royal Terrace.
1867. Sorley, John, LL.D., Birkenhead Cottage, Birkenhead.
1865. Soutter, James, merchant, 102 Princes Street.
1859. Spence, W., Sec., B. L. Co. Bank, 36 St Andrew Square.
1840.*Sprot, T., W.S., 10 Drummond Place.
1850.*Stark, James, M.D., F.R.C.P., F.R.S.E., 21 Rutland Street.
1870. Steel, James, 103 St Vincent Street, Glasgow.
1835.*Steele, Pat. S., merchant, Eastbourne House, Portobello.
1867. Steuart, Charles, jun., W.S., 8 Doune Terrace.
1847.*Steuart, James, W.S., 8 Doune Ter.
1838.*Stevenson, David, C.E., F.R.S.E., 84 George Street.
1840.*Stevenson, P., philosophical-instrument maker, 51 Geo. IV. Bridge.
1847.*Stevenson, Thomas, C.E., F.R.S.E., 84 George Street.
1863. Stewart, A. Duncan, C.E., 12 Castle Street.
1869. Stewart, James Lawson, architect Carluke.
1850.*Stewart, J. W., C.E., 13 Young St.
1865. Stewart, Neil, artist, 11 W. Richmond Street.
1864. Strong, Thomas, W.S., 2 Grosvenor St.
1857. Sturrock, John., jun., 3 Queen's Crescent, Newington.
1868. Sutter, Archibald, C.E., 9 Manor Place.
1846.*Swan, Prof. Wm., F.R.S.E., St Andrews
1858. Swann, J. R., builder, 21 Leith Walk.
1866. Syme, F. D., 14 Great King Street.

1858. Taplin, Thomas, M.D.
1862.*Tawse, John Wardrobe, W.S., 49 Queen Street.
1851. Tennant, Charles, St Rollox, Glasgow.
1851. Tennant, John, St Rollox, Glasgow.
1860. Thomson, Alex., teacher, 5-A George Square.
1860.*Thomson, C. W., C.A., 9 Blenheim Place.
1863. Thomson, R. W., C.E., 3 Moray Place *President.*
1839.*Thomson, W. T., F.R.S.E., 3 George Street.
1830.*Tod, Henry, W.S., 39 York Place.
1858.*Tod, James, advocate, 56 Northumberland Street.
1861. Tod, James, engraver, 3 St James' Sq.
1856. Tod, John, engineer, 29 Leith Walk.
1846.*Trevelyan, Arthur, of Pencaitland Tyneholm, Tranent.
1840.*Trevelyan, Sir Walter C., Bt., F.R.S.E., Wallington, Newcastle-on-Tyne.
1864. Trotter, Alexander, teacher, 59 George Street.
1869. Tunny, James Good, photographer, 93 Princes Street,
1840.*Turnbull, W., F.R.S.E., accountant, Royal Bank, 14 Landsdowne Cres.
1822.*Tweeddale, The Most Noble George, Marquis of, K.T., F.R.S.E., Yester House, Gifford.

1860. Vallance, George, merchant, 1 Gayfield Square.
1840.*Walker, William, surgeon and oculist, 47 Northumberland Street.
1859. Wallace, Alex., M.A., assist.-observer, Royal Observatory.
1856. Waterston, George, jun., stationer, 56 North Hanover Street.
1866.*Watherston, James, builder 8 Charlotte Place.
1866.*Watherston, William, builder, 8 Charlotte Place.
1840.*Watson, Henry George, C.A., 123 George Street.

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1860. Watson, John Kippen, F.R.S.E., treas. and manager, Edin. Gas-Light Company, 25 Waterloo Place, *Vice-President.*
1850.*Webster, Andrew, S.S.C., 3 Forth St.
1865. Welsh, Richd., coppersmith, 11 Calton Hill.
1861. Whimster, T., gas-engineer, Perth.
1867. Whitehead, John, S.S.C., 15 St Andrew Square.
1846.*Whitelaw, James, watchmaker, 30 W. Register Street.
1867. Whytock, A., merchant, 9 George Street.
1838.*Wilkie, John, of Foulden, Berwick-upon-Tweed.
1851. Willet, John, C.E., Aberdeen Railway.
1864. Wilson, Andrew, dentist. 21 Young St.
1867. Wilson, James T., manufacturing-chemist, Restalrig House.
1858. Wilson, John, coalmaster, South Bantaskine. Falkirk.
1859. Wilson, John, F.R.S.E., Professor of Agriculture, College.
1838.*Wilson, Patrick, architect, 2 Queen Street.
1868. Wilson, Robert, engineer, Patricroft.
1867. Wilson, Thos., teacher, Roberton, by Hawick.
1860. Wishart, Edward, merchant, 3 Laverock Bank Terrace, Leith.
1861. Wright, James, 13 Ainslie Place.
1836.*Wright, Robt., architect 22 George Square.
1863. Wright, Thomas Strethill, M.D. M.R.C.P.E., 55 Northumberland Street.
1859. Wyllie, J. S., 5 Viewforth Place.

1853. Young, James, chemical manufacturer Limefield, West Calder.
1859. Young, James, M.D., 36 Castle Street.
1860. Young, John, gas-engineer, Aspull Wigan.
1861. Younger, Robt., brewer, Croft-an-righ.

TOTAL ORDINARY FELLOWS, 410.

The following ORDINARY FELLOWS are ordered to remain, till they return to Scotland in the following

SUSPENSE LIST.

1859. Richard S. Culley, telegraph-engineer, General Post-Office, London
1868. Henry Dixon, New South Wales.
1860. Captain Sir Wm. Hamilton, Bart., Royal Artillery, Simla.
1868. N. B. M'Dermott, Jamaica.
1862. A. T. Machattie, Ph.D., Ontario Chemical Works, London, Canada West.
1870. John Menzies, C.E., Llanberis.
1853. James Newlands, C.E., Borough Engineer, Liverpool.
1846. Mungo Ponton, F.R.S.E., 3 Arlington Villas, Clifton.
1854. J. T. Thomson, C.E., Government Surveyor, Otago.
1854. Dr Daniel Wilson, Professor, Toronto, Canada. TOTAL, 10.

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APPENDIX (K.)

Proceedings of the Royal Scottish Society of Arts, Session 1870–71.

The Annual General Meeting of the Royal Scottish Society of Arts was held in their Hall, 117 George Street, on Monday, 14th November 1870,—John K. Watson, F.R.S.E., Vice-President, in the Chair.

The following Communications were made:—

1. An Address on Technical Chemistry, with Illustrations, by Stevenson Macadam, Ph.D., F.R.S.E., F.C.S., was given, and on the motion of Mr Charles Cowan, thanks were given to Dr Macadam, who was requested to allow it to be printed in the Society's Transactions.

2. The Report of the Prize Committee, awarding the prizes for Session 1869–70, was read, and the prizes were delivered by the President to the successful Candidates. (See Appendix M.)

The following Donations were laid on the table, and thanks voted to the respective Donors:—

1. Proceedings of the Royal Society, Nos. 120–122. Presented by the Society.
2. Journal of the Society of Arts, Nos. 918–936. Presented by the Society.
3. Engineering, Nos. 234–252. Presented by the Proprietors.
4. English Mechanic, Nos. 277–292. Presented by the Proprietors.
5. The Artizan, Nos. 7–11. Vol. IV. Presented by the Proprietors.
6. Proceedings of the Institute of Mechanical Engineers for April 1870. Presented by the Institute.
7. Journal of the Institute of Actuaries, Nos. 80, 81. Presented by the Institute.
8. Proceedings of the Royal Institution of Great Britain, Nos. 51–53. Presented by the Institution.

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9. Minutes of Proceedings of the Institution of Civil Engineers, Vols. XXIX., XXX. Presented by the Institution.

10. Journal of the Royal Dublin Society, No. 39. Presented by the Society.

11. Journal of the Scottish Meteorological Society, No. 27. Presented by the Society.

12. The Edinburgh University Calendar for 1870–71. Presented by Mr Ravenscroft.

13. Papers on Patents for Inventions. By St John V. Day. Presented by Mr Day.

14. The Industrial Settlement of Europeans in India. By Archibald Graham, M.D. Presented by Dr Graham.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Candidates were elected Ordinary Fellows:—

1. John Keane, C.E., Department of Public Works, Bengal.
2. James Mackenzie, 5 Grange Place.

III. In terms of Law XV. the Society elected its Office-Bearers for Session 1870–71, viz.:—

R. W. Thomson, C.E., F.R.S.E., 3 Moray Place, *President.*
John Paterson, C.E., 27 Hope Terrace,
Allan D. Stewart, C.E., 121 Princes Street, } *Vice-Presidents.*
Edward Sang, F.R.S.E., 2 George Street, *Secretary.*
John Scott Moncrieff, C.A., Chambers, 26 Frederick Street, *Treasurer.*
Stevenson Macadam, Ph.D., F.R.S.E., F.C.S., &c., Surgeons' Hall, Nicolson Street, *Editor of Transactions.*
Alexander Jamieson, 71 Adam Square, *Curator of Museum.*
Alexander Kirkwood, 9 St James' Square, *Medalist.*
John Bell, 117 George Street, *Officer and Collector.*

Councillors.

Robert H. Bow, C.E., F.R.S.E., 7 South Gray Street.
Adam Mossman, Jeweller, 30 Princes Street.
Charles Pearson, C.A., 128 George Street.
A. Brebner, C.E., 84 George Street.
George Harrison, Merchant, 12 Blackford Road.
Charles Macpherson, C.E., 10 Glengyle Terrace.
Professor Fleeming Jenkin, F.R.SS. L. & E., 5 Fettes Row.
D. C. Mudie, Panmure Foundry.
James Tod, 3 St James' Square.
John Sturrock, 3 Queen's Crescent.
John W. Tawse, W.S., 49 Queen St.
Alexander Reid, 31 Castle Street.

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IV. A List of the Office-Bearers, and an Alphabetical List of the Fellows, as at 1st November 1870, had been circulated with this day's Billet.

V. A copy of the Prize Committee's Report had also been enclosed.

Second Meeting—28th November 1870 —John Paterson, C.E., Vice-President, in the Chair.

The following Communications were made:—

1. Description of a New Hinge for the Doors of Writers' Pigeon-holes. By James Denham, cabinetmaker, 12 George Street. A specimen was exhibited, as also explanatory drawings (No. 4240).

The objects sought to be attained are to have the floor of the pigeon-hole level with the door when opened, and to avoid an unseemly gap when shut. The Secretary remarked that the hinge describes a line of the fourth order, and that Mr Denham has utilised that part of the curve which is almost straight. The communication was referred to a Committee.

2. Remarks on Warming and Ventilation. By James Kerr, Superintendent, Sheriff Court House (No. 4241).

This communication was also referred to a Committee.

3. Circular from the Royal Irish Academy as to the Preservation of the Art-Treasures in Paris.

After some discussion, on the motion of Mr Pearson, seconded by Mr Tawse, the Society, though sympathising in the object, resolved to take no action in the matter, as no benefit could be expected from their intercession.

Part II. of Vol. VIII. of the Transactions of the Society was laid upon the table.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 937–939. Presented by the Society.

2. Engineering, Nos. 253–255. Presented by the Proprietors.

3. English Mechanic, Nos. 293–295. Presented by the Proprietors.

4. Education and Status of Civil Engineers. Presented by the Institution of Civil Engineers.

5. Canadian Journal, Vol. XII. No. 6. Presented by the Canadian Institute.

6. Patent Office Report for 1867, Vols. I.–IV. Presented by the American Commissioners of Patents.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

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II. The following Gentlemen were elected Ordinary Fellows, viz.:—

1. Robert H. Smith, engineer, Lauriston Villa.
2. Francis Johnston de Soyres, engineer, 4 Morton Street.

Third Meeting—12*th December* 1870.—Dr Stevenson Macadam in the Chair.

The following Communications were made:—

1. On a Simple Means for the Better Distribution of Water into Household Cisterns. By John Winton, engineer, Portobello (No. 4246).

After a discussion, the paper was referred to a Committee.

2. Improvement on Keys or Wedges for securing Wheels to their Shafts. By Edward Sang, F.R.S.E. (No. 4244).

The improvement consists in placing the key diagonally, so that each key-seat is a right-angled isosceles triangle. Thanks were given for the communication.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 940, 941. Presented by the Society.
2. Engineering, Nos. 256, 257. Presented by the Proprietors.
3. English Mechanic, Nos. 296, 297. Presented by the Proprietors.
4. Journal of the Institute of Engineers in Scotland, Vol. XIII. Presented by the Institute.
5. The Artizan, Vol. IV. No. 12. Presented by the Proprietors.
6. The Architect, No. 100. Presented by the Proprietors.
7. The Journal of Applied Science, No. 12. Presented by the Editor.
8. The True Direction and Velocity of the Wind. By Rev. J. N. Miller. Presented by the Author.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. Thomas Sheriff, L.R.C.P. and S. Ed., Ratho, was elected an Ordinary Fellow.

Fourth Meeting—9*th January* 1871.—Allan D. Stewart, C.E., Vice-President, in the Chair.

The following Communications were made:—

1. Report of Committee on Mr Kerr's Paper on Warming and Ventilation (No. 4241) was read and adopted.
2. Report of Committee on Mr Winton's Means for Distributing Water (No. 4246) was read and adopted.

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3. On the Utilisation of Fibrous Cotton Seed. By Thomas Rose, of Rose & Gibson, Sankey Mills, Earlstown, Lancashire. Specimens and a model Crushing-Machine were exhibited.

Considerable discussion ensued, and the communication was referred to a Committee.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 942–945. Presented by the Society.
2. Engineering, Nos. 258–261. Presented by the Proprietors.
3. English Mechanics, Nos. 298–301. Presented by the Proprietors.
4. Proceedings of the Institution of Mechanical Engineers, Nottingham Meeting, Part II. Presented by the Institution.
5. Transactions of the Botanical Society, Vol. X. Part II. Presented by the Society.
6. Transactions of the Institution of Engineers in Scotland, 22d Nov. 1870. Presented by the Institution.
7. Report on the Invertebrata of Massachusetts. By Dr Augustus A. Goold.
8. Annual Report of the Smithsonian Institution.
9. Smithsonian Contributions to Knowledge, Vol. XVI.
10. Smithsonian Miscellaneous Collections, Vols. VIII. and IX.
11. Address on the Centennial Anniversary of Humboldt. By Louis Agassiz.
12. Report on the National Academy of Sciences, 1868.
13. Proceedings of the American Academy of Arts and Sciences, Vol. VIII.
14. Monthly Report on the Revenue of the United States, July, August, September 1869. Presented through the Smithsonian Institution.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. Robert Ferrier, inspector of gas meters, Royal Exchange, was elected an Ordinary Fellow.

III. The Society appointed a Committee to audit the Treasurer's books and to report, viz., Mr Tawse, Mr Rainie, and Mr Jobson Dickson, Convener.

Fifth Meeting—23*d January* 1871.—Thomas Stevenson, C.E., F.R.S.E., in the Chair.

The following Communications were made:—

1. Report of Committee on Mr St Clair's Embossed Music for the Blind (No. 4237) was read and adopted.

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2. On Rainfall and Evaporation in relation to Water Supply. By Alexander Leslie, C.E., Ass. Inst. C.E. (No. 4245), with Illustrations. (See paper printed in the Transactions, page 243.)

Considerable discussion took place, and the paper was referred to a Committee.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 946, 947. Presented by the Society.
2. Engineering, Nos. 262, 263. Presented by the Proprietors.
3. English Mechanic, Nos. 302, 303. Presented by the Proprietors.
4. Transactions of the Institute of Engineers in Scotland. Presented by the Institute.

PRIVATE BUSINESS.

The Minutes of last Meeting were read and confirmed.

Sixth Meeting—13*th February* 1871.—Allan Brebner, C.E., in the Chair.

The following Communications were made :—

1. Report of Committee on Dr Macadam's paper (No. 4238) on the Distillation of Coal Gas was read and adopted.
2. Short account of his Patent Process for manufacturing Cast-Steel. By Charles Attwood, Wolvingham, Darlington (No. 4248).

Specimens were exhibited. After some discussion, the thanks of the Society were voted to Mr Attwood.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 948–950. Presented by the Society.
2. Engineering, Nos. 264–266. Presented by the Proprietors.
3. English Mechanic, Nos. 304–306. Presented by the Proprietors.
4. Proceedings of the Royal Society, No. 124. Presented by the Society.
5. The Artizan, Vol. V. No. 2. Presented by the Proprietors.
6. The Architect, Vol. V. No. 106. Presented by the Proprietors.
7. Mechanic's Magazine, No. 2416. Presented by the Proprietors.
8. The Venture, the Blind Man's Quarterly, and
9. The Mastery of Languages. By Thomas Prendergast.
   Presented by the Rev. Robert Hugh Blair, M.A., F.R.A.S., Worcester.
10. Proceedings of the Institution of Mechanical Engineers for November 1870. Presented by the Institution.
11. Preliminary Experiments on Steel. Presented by the Committee of Civil Engineers.

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PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. Richard Anderson, manager Uddingston Oil Works, Glasgow, was elected an Ordinary Fellow.

Seventh Meeting — 27th February 1871. — Professor Fleeming Jenkin in the Chair.

The following Communications were made :—

1. Report of Committee on Mr Denham's new Hinge (No. 4240) was read and adopted.

2. Report of Committee on Mr Rose's paper (No. 4246) on the Utilisation of Fibrous Cotton Seed was read and adopted.

3. On Water Meters as in use by Water Companies, with Design for Simplifying and Cheapening them. By John Reid, Manager Edinburgh and Leith Gas Company (No. 4247). (See paper printed in the Transactions, p. 261.) Illustrative Drawings and Models in action were exhibited.

After a lengthened discussion, the paper was referred to a Committee.

4. On a new method of fixing Tubes in Vertical Steam Boilers. By the President, R. W. Thomson, C.E., F.R.S.E., with Drawings (No. 4251). (See paper printed in the Transactions, p. 297.)

Considerable discussion took place, and the paper was referred to a Committee.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 951, 952. Presented by the Society.

2. Engineering, Nos. 267, 268. Presented by the Proprietors.

3. English Mechanic, Nos. 307, 308. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. George Robertson Hislop, F.C.S., gas engineer, Blackston Road, Paisley, was elected an Ordinary Fellow.

III. The Report of the Auditing Committee on the Treasurer's books was read, and the Chairman granted discharge to the Treasurer in terms thereof.

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Eighth Meeting—13*th March* 1871.—Allan D. Stewart, Vice-President, in the Chair.

The following Communication was made :—

On Mineral Oils : the Advantages and Disadvantages attending their use ; their Employment for Lighthouse Illumination ; and a general uniform system for testing and regulating the sending of dangerous illuminating substances into commerce for sale. By Captain H. H. Doty, Norfolk, Virginia, U.S.A. (No. 4253). Diagrams were exhibited, as also various lamps, among which one for lighthouse purposes was shown in use.

A lengthened discussion followed, and the paper was remitted to a committee.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 953, 954. Presented by the Society.
2. Engineering, Nos. 269, 270. Presented by the Proprietors.
3. English Mechanic, Nos. 309, 310. Presented by the Proprietors.
4. Proceedings of the Royal Society, No. 125. Presented by the Society.
5. The Artizan, Vol. V. No. 3. Presented by the Proprietor.
6. Journal of the Institute of Actuaries, Vol. XVI. Part 2. Presented by the Institute.
7. Journal of the London Institution, Nos. 2, 3. Presented by the Proprietor.
8. Transactions of the Institute of Engineers in Scotland. Presented by the Institute.

PRIVATE BUSINESS.

The Minutes of the former Meeting were read and confirmed.

Ninth Meeting—27*th March* 1871.—Allan D. Stewart, Vice-President, in the Chair.

The following Communications were made :—

1. Notice of a New Form of Intermittent Light for Lighthouses. By Robert Louis Stevenson. With illustrative Drawings. (No. 4253.) (See paper printed in the Transactions, p. 271.)

A discussion followed, and the paper was remitted to a Committee.

2. A new Application of Principles to Ventilation. By H. F. Alexander. With illustrative Model. (No. 4254.)

After some discussion the paper was remitted to a Committee.

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The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 955, 956. Presented by the Society.
2. Engineering, Nos. 271, 272. Presented by the Proprietors.
3. English Mechanic, Nos. 311, 312. Presented by the Proprietors.
4. Journal of the Scottish Meteorological Society, Nos. 28, 29. Presented by the Society.
5. Transactions of the Institution of Engineers in Scotland. Presented by the Institution.
6. Proceedings of the Royal Society, No. 126. Presented by the Society.

PRIVATE BUSINESS.

I. The Minutes of the former Meeting were read and confirmed.

II. The following Gentlemen were elected Ordinary Fellows :—

1. Robert P. Beattie, plumber, 19 South Castle Street.
2. William Foulis, gas engineer, 42 Virginia Street, Glasgow.
3. B. M. Macrae, gas engineer, Peep-o'-Day House, Dundee.
4. Arthur Albert Macfarlane, V.S., 25 Blackhall Street, Greenock.
5. Robert C. S. Herbert, V.S., East Currie Farm, Currie.

Tenth Meeting—10*th April* 1871.—John Paterson, Vice-President, in the Chair.

The following Communications were made :—

1. Report of Committee on Mr Reid's paper on Water Meters (No. 4247) was read and adopted.
2. Report of Committee on Mr Thomson's new method of Fixing Tubes in Vertical Steam Boilers (No. 4251) was read and adopted.
3. The prize awarded to Mr James Mackenzie for his Railway Couplings was exhibited.
4. Note of Experiments with his new Water Meter, by John Reid, Manager of Edinburgh and Leith Gas Company, was read, and a full-sized Meter exhibited in action (Nos. 4247, 4255). (See paper printed in Transactions, p. 261.)

The communication was remitted to the former Committee.

5. Description of a new Steelyard Indicator. By James Mackenzie, Manager's Department, North British Railway (No. 4256). (See paper printed in Transactions, p. 275.) A Model and a full-sized Indicator were exhibited.

After remarks by several members, the paper was remitted to a Committee.

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6. Description of a Treasure-Safe for Ships. By Thomas B. Johnston, engraver, 4 St Andrew Square.

Some discussion ensued, and the paper was remitted to a Committee.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 957, 958. Presented by the Society.
2. Engineering, Nos. 273, 274. Presented by the Proprietors.
3. English Mechanic, Nos. 313, 314. Presented by the Proprietors.
4. Artizan, Vol. V. No. 4. Presented by the Proprietors.
5. Proceedings of the Institution of Mechanical Engineers, Jan. 1871. Presented by the Institution.

PRIVATE BUSINESS.

I. The Minutes of the former Meeting were read and confirmed.

II. An abstract of the Society's Income and Expenditure had been sent to each member along with his Billet.

III. The Society appointed a new Convener to the Committee on Mr Ayton's paper, No. 4231.

Eleventh Meeting—24*th April* 1871.—John Paterson, Vice-President, in the Chair.

The following Communication was made:—

On Recent Progress in Invention. By Professor Thomas C. Archer, Director of the Museum of Science and Art. (See Transactions, p. 286.) Numerous and interesting specimens were exhibited.

On the motion of Mr Ivory, seconded by Mr Tawse, a vote of thanks was awarded to Professor Archer.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 959, 960. Presented by the Society.
2. Engineering, Nos. 275, 276. Presented by the Proprietors.
3. English Mechanic, Nos. 315, 316. Presented by the Proprietors.
4 Journal of the London Institution, No. 4. Presented by the Institution.

PRIVATE BUSINESS.

I. The Minutes of the former Meeting were read and confirmed.

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II. On the recommendation of the Council (which recommendation had been printed in the Billet for the Meeting), the following Gentlemen were appointed as Publication Committee, viz. :—Dr R. M. Ferguson, Sheriff Hallard, William Lees, John Kippen Watson, John Paterson, The Treasurer, The Secretary, and Dr Stevenson Macadam, Editor and Convener.

Twelfth Meeting—8th May 1871.—John Paterson, Vice-President, in the Chair.

The following Communications were made :—

1. Report of Committee on Mr Aytoun's paper on Ventilation (No. 4231) was read and adopted.

2. Report of the Committee on Mr Alexander Leslie's paper on Rainfall (No. 4245) was read and adopted.

3. Report of Committee on Captain Doty's paper on Mineral Oils (No. 4252) was read and adopted.

4. On a new Danger Signal for Railways. By William Noble, millwright engineer (No. 4258). An Illustrative Model was exhibited.

After a few remarks by several members, the paper was remitted to a Committee.

5. On a Cheap and Effective Water Meter, suitable for Dwelling Houses. By Robert H. Bow, C.E., F.R.S.E. (No. 4261.) A meter was exhibited in action.

After remarks, the paper was remitted to a Committee.

6. Improvement in Safety Couplings for Railway Waggons. By Mr Noble. (No. 4259.) Drawings and Model of the Coupling were exhibited.

The communication was remitted to a Committee.

7. On Regulating the Pressure in Water-Pipes. By Mr Bow. (No. 4262.) An Illustrative Drawing was exhibited.

The paper was remitted to the Committee on No. 4261.

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 961, 962. Presented by the Society.

2. Engineering, Nos. 277, 278. Presented by the Proprietors.

3. English Mechanic, Nos. 317, 318. Presented by the Proprietors.

4. Journal of the Institute of Actuaries, No. 83. Presented by the Institution.

5. Proceedings of the Royal Society, No. 127. Presented by the Society.

6. Transactions of the Institution of Engineers in Scotland. Session 1870–71. Presented by the Institution.

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7. The Artizan, No. 5, Vol. V. Presented by the Proprietors.
8. The Insurance Record, No. 429. Presented by the Proprietors.

PRIVATE BUSINESS.

I. The Minutes of the former Meeting were read and confirmed.

II. In terms of Law XX., the Treasurer laid on the table a List of those Ordinary Members who are in arrears of their annual contributions.

Thirteenth Meeting—10*th July* 1871.—John Paterson, Vice-President, in the Chair.

The following Reports of Committees were read and adopted:—

1. On Mr R. L. Stevenson's Intermittent Light (No. 4253).
2. On Mr H. F. Alexander's Paper on Ventilation (No. 4254).
3. On Mr John Reid's Experiments with his Water-Meter (No. 4255).
4. On Mr James Mackenzie's Steelyard Indicator (No. 4256).
5. On Mr T. B. Johnstone's Treasure-Safe for Ships (No. 4257).
6. On Mr Noble's New Danger Signal (No. 4258).
7. On Mr Noble's Improvement on Safety Couplings (No. 4259).

The Secretary intimated that he had not yet received the report on Mr Bow's Papers (Nos. 4261, 4262), on account of the members being out of town; and the Society empowered him to send the report to the Prize Committee.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 963–971. Presented by the Society.
2. Engineering, Nos. 279–287. Presented by the Proprietors.
3. English Mechanic, Nos. 319–327. Presented by the Proprietors.
4. Proceedings of the Royal Society, No. 128. Presented by the Society.
5. Transactions of the Institution of Engineers in Scotland. Session 1870–71. Presented by the Institution.
6. Journal of the London Institution, Vol. I. No. 6. Presented by the Institution.
7. Canadian Journal, Vol. XIII. No. 1. Presented by the Canadian Institute.
8. Journal of the Scottish Meteorological Society, No. 30. Presented by the Society.

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9. Proceedings of the Philosophical Society of Glasgow, Vol. VII. No. 3. Presented by the Society.

10. Annual Report (38th) of the Royal Cornwall Polytechnic Society. Presented by the Society.

11. Edinburgh University Calendar, 1871–72. Presented by the Publisher.

12. Transactions and Proceedings of the Royal Society of Edinburgh, Session 1869–70. Presented by the Society.

PRIVATE BUSINESS.

I. The Minutes of the former Meeting were read and confirmed.

II. The following Gentlemen, who had been recommended by the Council, and whose names had been intimated in the Billet, were appointed as the Committee on Prizes, viz.:—

Messrs JOHN BELL.
CHARLES COWAN.
Dr R. M. FERGUSON.
GEORGE HARRISON.
THOMAS IVORY.
DAVID MARSHALL.
JOHN MILNE.
JOHN KOLBE MILNE.
D. C. MUDIE.
JOHN PATERSON.
CHARLES PEARSON.
ALLAN D. STEWART.
With the TREASURER and SECRETARY.

III. The Society remitted to the Council to arrange the celebration of the Society's Jubilee.

IV. The Society, after making a few alterations, approved of a printed "Note of the Ordinary Course of Procedure of the Society, for the information of Authors of Communications," which Note had been recommended by the Council. (See Appendix P.)

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APPENDIX (L.)

LIST OF PRIZE SUBJECTS FOR SESSION 1871-72.

THE ROYAL SCOTTISH SOCIETY OF ARTS proposes to award prizes of different values, of Thirty Sovereigns, and under, in Gold or Silver Medals, Silver Plate, or Money, for approved Communications, *whether previously published or patented, or not,* submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the *Mechanical* and *Chemical* Arts in general, and in their relation to the Fine Arts, and also to means by which the *Natural Productions* of the Country may be made more available. The Society suggests the following as a few of the many subjects that may be attended to, viz.:—

I. INVENTIONS, DISCOVERIES, OR IMPROVEMENTS in the Useful Arts.

1. *Mechanical Arts.*

INVENTIONS OR IMPROVEMENTS in applying the Motive Power of Men and Animals,—in Wind and Water Prime Movers,—in Steam and other Heat Engines, including Gas Engines,—in Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines,—in Cotton and other Textile Manufacturing Mills,—in Ship-building in Wood, Iron, and Steel,—in Lighthouses,—in Marine Propellers,—in Railways, Plant, and Signals,—in Electric Apparatus,—in Electro-Magnetic Motive Power,—in Electric and other Telegraphic Apparatus, Sub-Marine and Aërial,—in Photographic Apparatus,—in Fire-Proof Buildings,—in Water Supply,—in Paving,—Sewerage,—in Economical Appliances for increasing the Sanitary condition of Towns,—in Smoke Consumption and Extinguishing Fires,—in Gas-Works,—

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in Canals and Inland Navigation, including the application of Steam Power to Canal Traffic,—Canal Locks, Inclines, and Lifts,—Application of Hydraulic Power for Lifts for Domestic Use,—for Cranes,—Printing Presses,—Organ-Blowing, and other similar purposes, where small Propelling Power is required,—Labour-saving Machines for working in Wood,—in Tools, Implements, and Apparatus for the various Trades,—in Sewing Machines,—in Bricks, Encaustic Tiles, Cements and Mortars,—in Printing Machines, Cases, and Rollers,—in Stereotyping,—in Cranes,—in the Machinery for Collieries,—in preserving Timber and Metals in Marine Works,—in Optical Apparatus,—in Manufacture of Paper,—Experiments on the Effect of Low Temperatures on Metals.

2. *Chemical Arts.*

INVENTION or IMPROVEMENTS in new and useful applications of Gutta Percha and Vulcanised India Rubber, or similar Gums,—in the Economical Extraction of Chemical Principles or Useful Substances, as Paraffine, &c., from Coal,—Porcelain Clay from Granite or Felspar,—and Metals generally from their Ores and Oxides,—in Dyes,—in Paints,—in Paper,—in Glass, especially for Lenses,—in methods of rendering the Electric Light available in practice.

3. *Relative to the Fine Arts.*

INVENTIONS or IMPROVEMENTS in Photographic processes, in "Carbon" Printing, and in Methods of Printing Photographs from their Impressions on Steel or Copper Plates, or Lithographic Stones,—in Electrotype processes,—in Die-Sinking,—in methods of illustrating Books, to be printed with the letterpress,—in Paper-Hangings,—in Articles of Porcelain, Common Clay, or Metal,—in Glass-Staining,—in Engraving on Stone,—in Chromo-Lithography,—in "Nature" Printing.

4. *Natural Productions.*

DISCOVERY of Plumbago Mines,—Whetstones,—of Woods suitable for Engraving.

II. EXPERIMENTS applicable to the Useful Arts.

III. COMMUNICATIONS of Processes in the Useful Arts practised in this or other Countries, but not generally known.

IV. PRACTICAL DETAILS of Public or other Undertakings of National importance, already executed, but not previously published;—or valuable suggestions for originating such undertakings.

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The KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts, which shall be primarily submitted to the Society" during the Session.

The HEPBURN BIENNIAL PRIZE, value about £12.

(*If not awarded during Session* 1870–71.)

For such Inventions or Communications submitted to the Society as shall be approved of by the Society, or by their Prize Committee."

The MAKDOUGALL-BRISBANE BIENNIAL PRIZE, value £10.

(*If not awarded during Session* 1870–71.)

"To the Authors or Inventors of Communications of Merit, which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction."

The REID and AULD PRIZES.

For the First, Second, and Third best Models of "Anything New in the Art of Clock or Watch Making,—by Journeymen or Master Watch and Clock Makers,"—if these should be considered worthy of Prizes, the Year's Interest of the Reid and Auld Bequest, being about SEVEN GUINEAS, divided among them in such proportions as the Prize Committee shall fix, according to merit. To such as deserve it, the Society may add to the amount of the Prize out of its general funds.

GENERAL OBSERVATIONS

AND DIRECTIONS FOR PREPARING AND LODGING COMMUNICATIONS.

The descriptions of the various inventions, &c., must be *full* and *distinct;*—be legibly written on *Foolscap* paper, leaving margins at least one inch and a half broad, on *both sides of each page*, so as to allow of their being bound up in volumes; and, when necessary, be accompanied by *Specimens, Drawings, or Models.* All Drawings to be on *Imperial* Drawing-Paper, unless a larger sheet be requisite. The Drawings to be in *bold* lines, not less than a quarter of an inch broad, or *strongly coloured*, so as to be easily seen at about the distance of thirty feet when hung up in the Hall, and the Letters or Figures of Reference to be at least 1½ inch long. When necessary, smaller and more minutely detailed Drawings should

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accompany the larger ones, for the use of the Committees, having the same letters of reference. Short abstracts must accompany the papers.

The Society shall be at liberty to publish in their Transactions copies or abstracts of all papers submitted to them. All Models, Drawings, &c., for which Prizes are given, shall be held to be the property of the Society; but the Value of the Model, if retained, will be separately allowed for.

Communications, Models, &c., are to be addressed to the SECRETARY, 2 George Street, Edinburgh, Postage or Carriage paid; and should be lodged on *or before* 2*d January* 1871, in order to insure their being read and reported on during the Session (the ordinary Meetings of which commence in November 1871, and end in April 1872). Communications lodged after the 1st March may not be read or reported on till the following Session.

By order of the Society.

EDWARD SANG, *Secretary.*

EDINBURGH, *April* 1871.

*** *Copies for distribution may be had from the Secretary.*

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APPENDIX (M.)

REPORT

OF

THE COMMITTEE

APPOINTED BY

THE ROYAL SCOTTISH SOCIETY OF ARTS

TO AWARD PRIZES FOR COMMUNICATIONS READ AND EXHIBITED DURING SESSION 1870-71.

Your COMMITTEE having met and carefully considered the Communications laid before the Society, or reported on during the Session 1870–71, beg to report—

That the Special Thanks of the Society are due to STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S.,—for his "Discourse on Technical Chemistry," delivered, with numerous Illustrations,—on November 14th, 1870 (No. 4243).

And to Professor THOMAS C. ARCHER, F.R.S.E., Director of the Museum of Science and Art,—for his "Address on Recent Progress in Inventions,"—read, and profusely illustrated, on April 24th, 1871 (No. 4260).

That your Committee have awarded the following Prizes, viz.:—

1. To JAMES MACKENZIE, Manager's Department of the North British Railway Company,—for his "Description of a New Steelyard Indicator,"—read, and Model exhibited, on April 10th 1871.

A Keith Prize, value Ten Sovereigns.

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2. To JOHN REID, Manager of the Edinburgh and Leith Gas Company,—for his Paper on "Water Meters as in use by Water Companies," with Design for simplifying and cheapening them,—read, and illustrated by the New Meter in action, on February 27th, 1871 (No. 4247).

A Keith Prize, value Ten Sovereigns.

3. To STEVENSON MACADAM, Ph.D., F.R.S.E., M.C.S.,—for his Paper on the "Distillation of Gas from Coal in Short Time Charges, as compared with Long Time Charges,"—read, and illustrated by Tabular Diagrams, on July 11th, 1870 (No. 4238).

The Hepburn Prize, value Seven Sovereigns.

4. To ALEXANDER LESLIE, C.E., Assoc. Inst. C.E.,—for his Paper on "Rainfall and Evaporation in Relation to Water Supply,"—read, and illustrated by Tabular Diagrams, on January 23d, 1871 (No. 4245).

The Society's Silver Medal, value Seven Sovereigns.

5. To ROBERT WILLIAM THOMSON, C.E., F.R.S.E.,—for his "Description of a New Method of Fixing Tubes in Vertical Steam Boilers,"—read, and illustrated by Drawings, on February 27th, 1871 (No. 4251).

The Society's Silver Medal, value Five Sovereigns.

6. To ROBERT LOUIS STEVENSON,—for his "Notice of a New Form of Intermittent Light for Light-Houses,—read, and illustrated by Drawings, on March 27th, 1871 (No. 4253).

The Society's Silver Medal, value Three Sovereigns.

7. To JOHN ST. CLAIR, Teacher of Music,—for his "Description of a New System of Embossed Music for the Blind,"—read, and illustrative Specimens exhibited, on July 11th, 1870 (No. 4237).

The Society's Silver Medal, value Three Sovereigns.

8. To JAMES DENHAM, cabinet-maker,—for his "Description of a New Hinge for the Doors of Writers' Pigeon-Holes,"—read, and Specimen exhibited, on November 28th, 1870 (No. 4240).

The Society's Silver Medal.

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And that while *Thanks* are justly due to all those gentlemen who have sent Communications, the *Special Thanks* of the Society are due to the following gentlemen:—

1. To THOMAS ROSE, Sankey Mills, Earlstown,—for his "Paper on the Utilisation of Fibrous Cotton Seed,"—read, and illustrated by Specimens and Working Machinery, on January 9th, 1871 (No. 4246).

2. To Captain H. H. DOTY, Norfolk, Virginia, U.S.A.,—for his "Paper on Mineral Oils; the Advantages and Disadvantages attending their use; their Employment for Light-House Illumination, and on a General System for Testing and Regulating their Sale,"—read and illustrated by Lamps in Action, on March 13th, 1871 (No. 4252).

3. To ROBERT HENRY BOW, C.E., F.R.S.E.,—for his "Description of a Cheap and Effective Water Meter, suitable for Dwelling Houses,"—read, and Meter exhibited, on May 8th, 1871 (No. 4261), and for his Paper on "Regulating the Pressure in Water-Pipes," (No. 4262), read on the same evening.

All which is humbly reported, in name and by order of the Committee, by

EDWARD SANG,
Sec., Convener ex officio.

SOCIETY'S HALL, 117 GEORGE STREET.
14th October 1871.

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APPENDIX (N.)

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1869–70.

I. REVENUE AND EXPENDITURE.

I. GENERAL FUNDS.

Revenue.				Expenditure.			
Arrears of Annual Contributions received	£6	6	0	1. ORDINARY—			
Annual Contributions for Session 1869-70 received	247	16	0	Prizes awarded	£21	5	0
Compositions in lieu of Annual Contributions received, £8, 19s. 6d., whereof 5 per cent. applicable to Revenue, as recommended by Committee on Accounts	0	9	0	Printing and Advertising	39	18	8
				Expenses of the Society's Printed Transactions	57	6	10
				Fees to Committees for Reports	11	0	0
				Repairs, Furnishings, &c., for the Hall	9	5	6
				Salaries & Expenses of Collection	107	17	2
				Miscellaneous Payments	16	13	6
				Interest on Debt	12	0	8
	£254	11	0		£265	7	4
Excess of Expenditure over Revenue	64	17	1	2. EXTRAORDINARY—			
				New Stove for Premises under the Hall	5	2	6
				Expenses of Conversazione in Museum of Science and Art on 14th February 1870	48	18	3
	£319	8	1		£319	8	1

II. KEITH BEQUEST.

REVENUE.

Dividends from Edinburgh Gas-Light Company's Stock	£15	0	0
Dividends from British Linen Company Bank Stock	13	0	0
Dividends from Royal Bank Stock	19	12	6
Interest on Bank Account	0	11	7
Amount	£48	4	1

EXPENDITURE.

Prize Awarded	30	0	0
Excess of Revenue	£18	4	1

III. REID AND AULD BEQUEST.

REVENUE.

Dividends from National Bank Stock	£13	0	0
Interest on Sums in Bank	4	3	0
Amount	£17	3	0

IV. BRISBANE BIENNIAL PRIZE FUND.

REVENUE.

Dividends from Government Stock	£5	3	1
Interest on Bank Account	0	2	8
Amount	£5	5	9

EXPENDITURE.

Prize Awarded	6	0	0
Excess of Expenditure	£0	14	3

V. HEPBURN PRIZE FUND.

REVENUE.

Dividends from Caledonian Railway Company Stock	£7	5	10
Interest on Bank Account	0	2	1
Amount	£7	7	11

EXPENDITURE.

Prize Awarded	7	0	0
Excess of Revenue	£0	7	11

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I. REVENUE AND EXPENDITURE—continued.

VI. BUILDING FUND.

REVENUE.

Rents drawn from Letting of Hall		£118	3 10
Interest on Bank Account		0	1 8
		£118	5 6

EXPENDITURE.

Payments on account of Hall, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, &c., and Hall Keeper's Salary	£88 16 8½		
Interest at 4 per cent. on Loans towards purchase of premises...	26 19 9		
		115	16 5
Excess of Revenue.....		£2	9 0

NOTE.—These Loans have been paid off, and the amount, £700, charged against the General Fund.

II. FUNDS OF THE SOCIETY.

As at 15th November 1870, *per Report of Committee on Books and Accounts.*

I. GENERAL FUND.

1. Price of Hall in George Street and Furnishings, and of the additional Premises purchased at Whitsunday 1863		£2,712	0 3
2. Arrears of Annual Contributions		36	15 0
		£2,748	15 3
Less—1. Balance due to Commercial Bank	£623 9 2		
2. Balance due to Treasurer	62 13 6		
3. Balance of Subscriptions for Expenses of Conference on Technical Education unexpended.....	9 5 2		
		695	7 10
AMOUNT		£2,053	7 5

II. KEITH BEQUEST.

1. Six Shares of the Edinburgh Gas-Light Company, at £53 ...	£318 0 0		
2. £100 Stock of the British Linen Company's Bank	272 0 0		
3. £250 Stock of the Royal Bank, at £179.....	447 10 0		
4. Balance in Commercial Bank.. .....£50 18 5			
Less—Balance due to Treasurer. 1 1 9			
	49 16 8		
AMOUNT		1,087	6 8

III. REID AND AULD BEQUEST.

1. £100 National Bank Stock	£276 0 0		
2. Balance in Bank	172 16 3		
AMOUNT		448	16 3

IV. BRISBANE PRIZE FUND.

1. £175, 3 per cent. Consols, at 92⅜.....	£161 13 1		
2. Balance in Bank	11 0 8		
AMOUNT		172	13 9

V. HEPBURN PRIZE FUND.

1. £100 Stock of the Scottish Central Railway Company	£144 0 0		
2. One £10 Share, No. 2, 4½ per cent. Preference Stock of do.	9 8 0		
3. Balance in Bank	10 9 4		
AMOUNT		163	17 4

VI.

Balance of Subscriptions for Expenses of Conference on Technical Education unexpended.....		9	5 2
Total value of Property and Funds under charge of the Society as at 15th November 1870		£3,935	6 7

JOHN SCOTT MONCRIEFF, *Treasurer.*

EDINBURGH, 3*d April* 1871.

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APPENDIX (O.)

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS,

AS AT 1st NOVEMBER 1871.

THE QUEEN, PATRONESS.

OFFICE-BEARERS FOR SESSION 1870-71.

President,	R. W. Thomson, C.E., F.R.S.E., 3 Moray Place.
Vice-Presidents,	John Paterson, C.E., 27 Hope Terrace. Allan D. Stewart, C.E., 121 Princes Street.
Secretary,	Edward Sang, F.R.S.E., 2 George Street.
Treasurer,	John Scott Moncrieff, C.A., Chambers, 26 Frederick Street.
Editor of Transactions,	Stevenson Macadam, Ph.D., F.R.S.E., F.C.S., &c., Surgeon's Hall, Nicolson Street.
Curator of Museum,	Alexander Jamieson, Nicolson Square.
Medalist,	Alexander Kirkwood, 9 St James' Square.
Officer and Collector,	John Bell, 117 George Street.

Councillors.

*Robert H. Bow, C.E., F.R.S.E., 7 South Gray Street.	*Charles Macpherson, C.E., 10 Glenglye Terrace.
*Adam Mossman, Jeweller, 30 Princes Street.	Professor Fleeming Jenkin, F.R.SS. L. & E., 5 Fettes Row.
*Charles Pearson, C.A., 128 George Street.	D. C. Mudie, Panmure Foundry.
*A. Brebner, C.E., 84 George Street.	James Tod, 3 St James' Square.
George Harrison, Merchant, 12 Blackford Road.	John Sturrock, 3 Queen's Crescent.
	John W. Tawse, W.S., 49 Queen St.
	Alexander Reid, 31 Castle Street.

The four Ordinary Councillors marked * retire by rotation, and Mr Macpherson has resigned.

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LIST OF THE ORDINARY FELLOWS,

AS AT 1st NOVEMBER 1871.

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1822 *ABERCORN, His Grace James, Duke of, K.G., &c., Hampden House, London
1850 *Adie, A.J., F.R.S.E., C.E., 5 St Andrew Square
1860 Adie, Richard, optician, 50 Princes Street
1863 Aitchieson, Thos. Stodart, 85 South Back of Canongate
1860 Aitchison, William John, 11 Buckingham Terrace
1865 Aitken, Henry, manager, Darroch Coal and Iron Works, Falkirk
1868 Aitken, William, accoucheur, Eastwood, Carnwath
1860 Alder, Henry, gas-meter maker, 32 Grange Road
1851 *Alexander, William, M.E., 23 India Street, Glasgow
1841 *Anderson, Charles W., merchant, 2 Mansion House Road
1871 Anderson, Richard, manager, Uddingstone Oil Works, Glasgow
1850 *Anderson, Thos., M.D., F.R.S.E., Professor of Chemistry, University, Glasgow
1863 Andrews, James, C.E., 84 George St.
1861 Archer, Thos. C., Director of the Museum of Science and Art
1868 Archibald, John, M.D., Biggar
1826 *Aytoun, Robert, W.S., 3 Fettes Row
1867 *Baillie, John M., C.A., 15 Northumberland Street
1869 Baxter, Sir David, Bart. of Kilmaron, 5 Moray Place
1865 Beattie, Adam, builder, 3 Chalmers Street
1871 Beattie, Robert P., plumber, 19 South Castle Street
1861 Beith, Donald, W.S., 43 Castle Street
1859 *Bell, Andrew Beatson, advocate, Court-House, Cupar-Fife
1857 Bell, B., surgeon, 8 Shandwick Place
1858 Bell, James, railway-engineer, 28 Brighton Place, Portobello
1867 Bell, Robert, coal-merchant, Wishaw
1861 Bell, William, stockbroker, 8 North St David Street
1867 Bennet, James Henry, engineer, 4 Summerfield, Leith
1861 Bernard, James A., 4 Manor Place
1847 *Bernard, Thomas, brewer, 8 Leopold Place
1861 Bethune, Norman, M.D.
1859 Black, Adam, publisher, 38 Drummond Place
1850 *Black, Rev. Arch. Pollok, LL.D., The Manse, Bow Road, London
1868 Blair, Rev. Rob. Hugh, rector of St Michael's, Worcester
1863 *Blanshard, George, wholesale druggist, 7 Carlton Terrace
1849 *Bouch, Thomas, C.E., 78 George Street
1853 *Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street
1863 Bowie, Andrew F., 4 Pilrig Street
1870 Boyd, George Pratt, gas engineer, Alloa
1868 Boyd, James L., S.S.C., 1 Regent Ter.
1848 *Brebner, Alan, engineer, 84 George Street
1861 Brown, D. R., manufacturing chemist, 1 St John Street
1864 Brown, Geo. Bruce, architect, 26 Elder Street
1839 *Brown, Thos., architect, 19 St Andrew Square
1868 *Bruce, C., banker, 2 Glenfinlas Street
1850 *Bruce, George Cadell, C.E., 21 Castle Street
1833 *Bryce, David, architect, 131 George St.
1851 *Bryden, J., bell-hanger, 55 George St.
1857 Bryson, J. M., optician, 60 Princes Street
1860 Bryson, Robt., watchmaker, 66 Princes Street
1822 *BUCCLEUCH and QUEENSBERRY, His Grace Walter, Duke of, K.G., A.M., F.R.SS. L. & E., Dalkeith Palace
1851 *Cadell, Henry, M.E, Grange, Bo'ness
1846 *Callender, John A., merchant, India Buildings
1859 *Cameron, P., contractor, 25 George Square
1834 *Campbell, Alex., brewer, 6 Charlotte Square
1862 Carlisle, James, engineer, 5 Hope Park Crescent
1865 *Carmichael, Peter, Den's Works, Dundee
1858 Carphin, James R., C.A., 26 Northumberland Street

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1840 *Carstairs, Drysdale, merchant, Liverpool
1864 Carter, Frederick Hayne, C.A., 8 Eton Terrace
1867 *Cay, Wm. Dyce, C.E., 7 Blackford Road
1864 Chalmers, T., Longcroft, Linlithgow
1860 Charnock, Richard Stephen, 8 Gray's Inn Square, London
1857 *Chaumont, F. D., M.D., 1st Battalion Rifle Brigade, Woolston, Southampton
1861 Chisholm, David, actuary, 9 Rill Bank Terrace
1856 *Chisholm, John Knox, dentist, 15 Duke Street
1860 Christie, John, Brae Lodge, Murrayfield
1866 Clapperton, W. R., merchant, 59 Princes Street
1862 Copland, Harry Y. D., 27 Stafford St.
1847 *Cousin, David, city-architect, City Chambers
1869 Cousin, George, architect, 5 Bruntsfield Terrace
1836 *Cowan, Charles, Wester Lea, Murrayfield
1864 Cox, John, glue manufacturer, Gorgie House, Murrayfield
1859 Cox, Robert, W.S., 25 Rutland Street
1863 Craig, David, paper-maker, 10 John Street, Portobello
1866 *Craig, James, distiller, 33 Manor Pl.
1865 *Craig, Robert, paper-maker, Craigesk, Dalkeith
1832 *Craig, Sir William Gibson, of Riccarton, Bart, F.R.S.E., Hermiston
1860 Cuningham, Alex., secretary to the Commissioners for Northern Lights, 84 George Street
1851 *Cunningham, George, C.E., 2 Ainslie Place
1857 *Cunningham, James, W.S., F.R.S.E., 50 Queen Street
1863 Currie, Heriot, engineer, 4 Auburn Place North Leith
1867 Cusiter, G. F., gas-engineer, Dalkeith

1868 Davidson, James, M.E., Newbattle
1869 Davies, William Henry, carver and gilder, 89 George Street
1850 *Davison, Samuel D., Boswell House, Wardie
1865 Day, St John Vincent, C.E., 166 Buchanan Street, Glasgow
1867 Deans, Peter Dods, Mount Charles, Bath Street, Portobello
1865 Deas, James, C.E., Glasgow
1844 *Dickson, J. Jobson, C.A., 13 Clarendon Crescent
1850 *Dickson, John, junior, gunmaker, 63 Princes Street
1866 Dods, G., assessor of railways, 5 Gayfield Square
1860 *Douglas, F. Brown, 21 Moray Place
1859 *Dryborough, Rich., cooper, 4 Hermitage Place, Leith
1866 Dunn, John H., 13 Glengyle Terrace
1844 *Dunn, Thos., optician, 7 Buccleuch Place

1853 Elliot, Professor James, Goldielands, Hawick
1839 *Ellis, T., upholsterer, 21 George IV. Bridge
1864 Ellis, W. M., merchant, 8 Wellington Street, Portobello
1857 Esson, Geo. A., accountant in Bankruptcy, 10 Great King Street

1850 *Falshaw, James, C.E., 26 Castle Street
1864 Ferguson, John, engraver, North St Andrew Street
1857 Ferguson, R. M., Ph.D., F.R.S.E., 12 Moray Place
1850 *Ferguson, William Black, C.E., 129 Union Street, Aberdeen
1871 Ferrier, Robert, inspector of gas meters, Royal Exchange
1869 Fidler, Thomas Claxton, C.E., Olney, Bucks
1864 Field, Thomas, slate-merchant, 27 Frederick Street
1860 Firth, William, secy., N. B. Rubber Co., Rose Villa, Viewforth
1840 *Fleming, Alex., W.S., 20 Lynedoch Place
1861 Fleming, A. B., chemical manufacturer, 12 Eton Terrace
1868 Forman, John, 51 Great King Street
1869 Forrest, Thomas, junior, ironmonger, 29 South Clerk Street
1840 *Forrester, John, W.S., 8 Drummond Place
1871 Foulis, William, gas engineer, 42 Virginia Street, Glasgow
1850 *Fraser, Alexander, printer, Old Fish-market
1847 *Fullarton, John A., publisher, 12 Claremont Street

1869 Galt, Robert, jun., coal-master, 20 Buchanan Street, Glasgow
1856 *Geddes, A. C., C.E.
1856 *Geddes, G. H., M.E., 9 Lynedoch Place
1842 *Gillespie, John, W.S., 53 Northumberland Street
1854 *Girdwood, Robert, merchant, 77 Great King Street
1850 *Glennie, Geo., C.E., 43 Upper Thames Street, London
1859 Gordon, Alexander, colliery manager, Thorniebank, Dalkeith
1861 Gowans, Alex., 3 Viewforth Road

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1850 *Gowans, James, builder, 31 Castle Ter.
1865 Gray, Alex., ironmonger, 85 George Street
1832 *Gray, James, ironmonger, 39 Gt. King Street
1860 Gray, Rev. W. H., M.A., minister of Lady Yester's, 5 Regent Terrace
1850 Gregory, Thos. Currie, C.E., Glasgow
1858 Greig, David, engineer, Greenhill Park
1835 *Groat, A. G., of Newhall, 12 Hart Street

1855 Hallard, Fredk., F.R.S.E., Sheriff-substitute of Edinburgh, 7 Whitehouse Terrace
1833 *Hamilton, Alexander, W.S., LL.B., F.R.S.E., 35 Queen Street
1860 Hardie, Walter, printer, 77 Rose Street
1866 Harrison, G., merchant, 12 Blackford Road
1855 Hart, Wm., phil.-instrument maker, Short's Observatory
1870 Hartnell, Wilson, engineer, 123 Everton Road, Manchester
1840 *Harvey, Sir George, P.R.S.A., F.R.S.E., 21 Regent Terrace
1853 *Hay, Geo. W., of Whiterigs, F.R.S.E., Devon Lodge, Starecross, Devon
1835 *Hay, James, F.R.S.E., merchant, Leith
1867 Hay, William, architect, 17 Hill Street
1863 Henderson, Robert, builder, 21 West Maitland Street
1856 Henry, Alex., gunmaker, 12 South St. Andrew Street
1836 *Hepburn, J. Stewart, of Colquhalzie, Auchterarder
1871 Herbert, R.C.S., veterinary surgeon, East Currie Farm, Currie
1839 *Hill, Laurence, jun., C.E., Inch Works, Port-Glasgow
1871 Hislop, George Robertson, F.C.S., gas engineer, Blackstone Road, Paisley
1863 Hogue, D. W., M.D., dentist, 65 Queen Street
1864 *Hood, Archibald, M.E., Whitehill Colliery, Lasswade
1870 Horne, Robert Reston, Kenmuirhill Colliery, Toll Cross, Glasgow
1868 Horsburgh, John, photographer, 131 Princes Street
1834 *Horsburgh, Robt., Southbank House, Penicuik
1863 Hossack, B. H., teacher, 33 Charlotte Square
1838 *Hunter, Richard, H.E.I.C.S., 10 Ainslie Place
1856 Hunter, Robert, advocate, Sheriff of Buteshire, 67 Northumberland St.

1857 Imlach, Francis B., F.R.C.S.E., 48 Queen Street

1859 Ivory, Thomas, advocate, 23 Walker Street

1854 Jackson, Ed. James, B.A. Oxon., 6 Coates Crescent
1850 *Jardine, Wm. Alex., C.E., 19 Queen Street
1848 *Jefferiss, Robert R., M.D., Dalkeith
1868 Jenkin, Fleeming, F.R.SS. L. & E., Professor of Civil Engineering, 5 Fettes Row
1858 Johnston, Adam, solicitor, 1 Register Place
1867 Johnstone, James, of Larchhill, 9 Royal Terrace
1850 *Johnstone, William, C.E., 14 Bridge Street, Glasgow
1850 *Jopp, Charles, C.E., 3 Royal Terrace

1857 Kay, John Zuill, Phœnix Iron Works, Glasgow
1870 Keane, John, C.E., office of Public Works, Calcutta
1839 *Kennedy, Wm., W.S., 59 Northumberland Street
1867 Kennedy, W. Wemyss, machinist, 111 Princes Street
1865 Kerr, John F., gas-engineer, Copiapo, Chili
1836 *Kirkwood, Alex., *Medalist*, 9 St James' Square
1857 Kirkwood, Wm. B., accountant, 6 St Andrew Square

1861 L'Amy, Sylvester
1857 Landale, And., iron-master, Lochgelly
1852 *Landale, David, M.E., 6 Forth Street
1868 Landale, James, M.E., 6 Forth Street
1836 *Lawson, Charles, of Borthwick Hall, 35 George Square
1858 Lawson, Charles, jun., seedsman, 34 George Square
1859 Lawson, George Stodart, 35 George Square
1836 *Lees, George, LL.D., St Andrews
1850 *Lees, Henry, accountant, 6 York Place
1856 *Lees, William, A.M., Linkvale, Viewforth
1866 *Leslie, Alexander, C.E., 39 Northumberland Street
1850 *Leslie, James, C.E., 72 George Street
1850 *Lessels, John, architect, 21 Heriot Row
1863 Lockhart, James, engineer, 2 Cecil Street, Glasgow
1852 Lorimer, James, C.E., 99 George St.
1862 Lundy, J. J., Assembly Street, Leith

1856* Macadam, Stevenson, Ph.D., F.R.S.E., *Editor of Trans.*, Surgeons' Hall
1839 *Macbrair, David J., S.S.C., 12 Great King Street

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1870 M'Connell, Frederick, of Robgill, Kirtle Lodge, Trinity
1871 MacCrae, B.M., gas engineer, Peep-o-day House, Dundee
1850 *Macdonald, D., cotton-spinner, Aberdeen
1866 Macdougall, William, C.E., 17 Buckingham Terrace
1871 Macfarlane, Arthur Albert, veterinary surgeon, 25 Blackhall St., Greenock
1868 Macfarlane, Walter, Saracen Foundry, Glasgow
1861 M'Glashan, Stewart, sculptor, Canonmills Bridge
1850 *Mackay, John, pharmaceutical chemist, 121 George Street
1861 Mackenzie, Charles, bookseller, 40 Greenhill Gardens
1868 Mackenzie, James, chemist, 49 George IV. Bridge
1870 Mackenzie, James, 5 Grange Place
1870 Mackenzie, William, gas manager, Dunfermline
1839 *Maclagan, Douglas, M.D., F.R.S.E., Prof. of Medical Jurisprudence, 28 Heriot Row
1870 Maclagan, John Thomson, manufacturing chemist, 7 James Place, Leith
1863 *Maclagan, Peter, of Pumpherston, M.P., Mid-Calder
1867 *Maclagan, R. Craig, M.D., 5 Coates Crescent
1866 M'Laren, Duncan, M.P., Newington House
1858 M'Lean, Hector Frederick, W.S., 3 Hill Street
1868 M'Leod, William Bowman, dentist, 43 George Square
1861 M'Nab, John, Inglis Green, Slateford
1861 Macnair, John, 33 Moray Place
1867 Macnaughton, Alexander, S.S.C, 18 Young Street
1863 Macnie, John, gas-engineer, Lecky Road, Londonderry
1861 Macpherson, Chas., C.E., 10 Glengyle Terrace
1850 *Marjoribanks, William, merchant, Warriston House
1867 Marshall, David, engineer, 6 Bernard Street, Leith
1843 *Marshall, G. H., jeweller, 3 Heriot Row
1858 Marshall, Thomas R., goldsmith, East Castle Road, Merchiston
1860 Marshall, William, engineer, Madeira Street, North Leith
1870 Marshall, William, coal-merchant, 14 South Charlotte Street
1869 Mason, Samuel Lack, general manager, North British Railway, Pentland Villa, West Coates
1860 Matheson, Robert, architect, 25 Abercromby Place
1850 *Mein, Archibald, dentist, 94 George St.
1861 Meldrum, Edward, of Dechmont, Broxburn
1860 Melville, F. Suther, assistant-clerk of Session, 4 Abbotsford Park
1850 *Melville, Jas. M., W.S., 110 George Street
1863 Menzies, Duncan, architect, 13 Young Street
1865 Menzies, Wm. John, W.S., Canaan Cottage
1857 *Millar, John, merchant, 13 York Place
1870 Miller, Rev. James N., 2 Upper Gilmore Place
1829 *Miller, Jn., of Leithen, C.E., F.R.S.E. M.P., 2 Melville Crescent
1868 Miller, Richard R., Upper Hermitage
1861 Millidge, J. J., goldsmith, 28 Princes Street
1859 *Miln, James, of Murie
1865 Milne, James, engineer, 16 Windsor Terrace, Glasgow
1848 *Milne, John Kolbe, dressing-case maker, 126 Princes Street
1859 *Milne, John, 44 Albany Street
1850 *Moffatt, William Lambre, architect, 23 Minto Street
1838 *Moncrieff, John Scott, C.A., *Treasurer*, 26 Frederick Street
1865 Moore, Wm., M.E., 49 West George Street, Glasgow
1863 More, James L., writer, 25 Scotland Street
1854 Morrison, Adam, S.S.C., 45 York Place
1838 *Morton, Hugh, engineer, Victoria Dock, Leith
1855 *Mossman, Adam, jeweller, 30 Princes Street
1858 Mudie, D. C., Panmure Foundry, North Back of Canongate
1857 Muir, John, brewer, 5 Pilrig Street
1857 Muir, R. G., brewer, 9 Bellevue Ter.
1869 Muir, William Hamilton, of Shawhill, 18 Picardy Place
1866 Muir, W. J. Cockburn, C.E., 9 Victoria Chambers, Westminster, London
1861 Muirhead, And., painter, 32 Frederick Street
1868 Murray, John, 48 Castle Street
1838 *Nachot, H. W., Ph.D., teacher of German, 73 Queen Street
1868 Nairn, Andrew, 21 Albany Street, Leith
1860 Nelson, Thomas, publisher, Hope Park
1858 Nicol, John, chemist, 4 Dundas St.
1850 *Ogilvie, A., merchant, Old Liston, Ratho

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1866 Oliver, John S., merchant, 8 Greenhill Park
1860 Ower, C., engineer, Craigie Terrace, Dundee

1865 Park, Ebenezer, engineer, 18 Greenside Lane
1863 Park, James Dove, engineer, 18 Greenside Lane
1866 Parkes, S. H., 5 St Mary's Road, Birmingham
1844 *Paterson, John, C.E., 27 Hope Terrace, *Vice-President*
1846 *Paterson, W., Scot. Cent. Rail., Perth
1859 Paterson, Wm., banker, 4 Regent Ter.
1868 Paton, Samuel, teacher, Lamington
1840 *Pearson, Charles, C.A., 128 George Street
1861 Peebles, D. B., engineer, 18 Viewforth Terrace
1865 *Peters, A. M., plumber, 13 Dundas St.
1862 Pilkington, F. T., architect, 2 Hill St.
1861 Platt, Leon J., dentist, Stirling
1868 Potts, R. Collins, 15 Henderson Place, Ferry Road
1864 Proudfoot, David C., City Road Trust, 13 Glengyle Terrace

1862 Rainie, Robert, C.A., 6 Clifton Ter.
1850 *Ramsay, Alex., Greenhill Park
1835 *Ranken, Francis, glass-merchant, 16 Picardy Place
1842 *Rankine, W. J. Macquorn, F.R.SS. L. and E., Prof. of Civil Engineering, 59 St Vincent Street, Glasgow
1857 *Reid, A., optician, 31 Castle Street
1860 Reid, John, engineer, Edin. and Leith Gas Co., 2 Queen's Place, Leith
1848 *Reid, R. L., painter, 2 Blenheim Place
1843 *Rhind, David, F.R.S.E., architect, 54 Great King Street
1850 *Richardson, R., merchant, 16 Bruntsfield Place
1865 Riddock, Jn., teacher, Neston, Cheshire
1853 Ritchie, A., watchmaker, 29 Leith St.
1867 Ritchie, David, smith, 14 Lauriston Gardens
1865 Ritchie, Frederick James, clockmaker, 25 Leith Street
1862 Ritchie, James, wholesale stationer, 13 Blacket Place
1866 Ritchie, Jas., watchmaker, 25 Leith Street
1870 Roberts, George, builder, 1 Grosvenor Street
1843 *Roberts, W. A., M.D., dentist and surgeon, 30 Queen Street
1866 Robertson, Andrew, secretary, Scottish Provincial Assurance Company, 5 Howard Place
1859 Robertson, G., M. Inst. C.E., F.R.S.E., 47 Albany Street
1855 Robertson, J., druggist, 35 George Street
1864 Robertson, Wm., engineer, 16 Madeira Street, Leith
1857 ROLLO, Right Hon. Lord, Duncrub House, Bridge of Earn
1868 Romanes, George, C.E., 5 St Andrew Square
1853 *Rose, J. T., shipbuilder, 1 Duncan Street, Drummond Place
1868 Rowan, Thos., North Woodside House, Glasgow
1869 Rowatt, Thomas, lamp-manufacturer, Palmerston Road
1867 Rowbotham, Rev. Frederick, M.A., 3 Bellevue Place
1838 *ROXBURGHE, His Grace James H. R., Duke of, K.T., Floors, Kelso
1866 Russel, John, merchant, 4 Baxter's Place
1835 *Russell, J. Scott, C.E., F.R.SS. L. & E., Sydenham, London

1864 Samuel, Peter, merchant, 15 Hanover Street
1843 *Sanderson, J. H., lapidary, 92 Princes Street
1867 Sanderson, William, rectifier, Quality Street, Leith
1869 *Sang, David, 9 Brandon Street
1828 *Sang, Edward, F.R.S.E., 2 George Street, *Secretary*
1860 Sang, Edward Elmslie, C.E., 2 George Street
1843 *Schenck, Frederick, lithographer, 11 Lothian Street
1870 Scott, Robert, Addiewell Chemical Works, West Calder
1850 *Scrymgeour, Henry, upholsterer, 73 George Street
1851 *Seton, Lt.-Col. R.S., Madras Artillery, 9 Windsor Street
1843 *Shanks, Thomas, engineer, Johnston, Renfrewshire
1869 Shaw, P., contractor, 6 Cambridge Street
1862 *Shedden, Thomas, M.A., Arrochar
1870 Sheriff, Thomas, L.R.C. Ph. and S. Ed., The Villa, Ratho
1866 Sim, Francis Ranken, glass-merchant, 96 Princes Street
1863 Sim, William, Edinburgh Colour Works, Jane Street, Leith Walk
1865 Simpson, George, Bonhar Colliery, Whitburn
1864 Simpson, James, architect, Daisy Bank, Ferry Road
1856 Slight, G. H., engineer, North Esk Mill, Dalkeith
1862 Sligo, A. V. S., of Inzievar, 5 Drummond Place
1854 Small, John, librarian, University

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1857 Smith, Adam G., C.A., 5 Lennox Street
1850 *Smith, A., C.E.
1839 *Smith, D., F.R.S.E., manager, North British and Mercantile Insurance Co., 64 Princes Street
1865 Smith, David, contractor, 61 Brougham Street, Belfast
1865 Smith, John D., carver and gilder, 21 Frederick Street
1870 Smith, Robert H., engineer, Lauriston Villa
1856 Smith, Robt. M., F.R.S.E., merchant, 4 Bellevue Crescent
1859 Smith, William, lithographer, 43 Northumberland Street
1855 Symth, Chas. Piazzi, F.R.SS. L. & E., Astronomer-Royal for Scotland, 15 Royal Terrace
1865 Soutter, James, merchant, 102 Princes Street
1859 Spence, W., Sec., B. L. Co. Bank, 36 St Andrew Square
1540 *Sprot, T., W.S., 10 Drummond Place
1850 *Stark, James, M.D., F.R.C.P., F.R.S.E., 21 Rutland Street
1870 Steel, James, 103 St Vincent Street, Glasgow
1835 *Steele, Pat. S., merchant, Eastbourne House, Portobello
1867 Steuart, Charles, jun., W.S., 8 Doune Terrace
1847 *Steuart, James, W.S., 8 Doune Ter.
1838 *Stevenson, David, C.E., F.R.S.E., 84 George Street
1840 *Stevenson, P., philosophical-instrument maker, 5 Forrest Road
1847 *Stevenson Thomas, C.E., F, R.S.E., 84 George Street
1863 Stewart, A. Duncan, C.E., 121 Princes Street, *Vice-President*
1869 Stewart, James Lawson, architect, Carluke
1850 *Stewart, J. W., C.E., 13 Young St.
1865 Stewart, Neil, artist, 11 W. Richmond Street
1864 Strong, Thomas, W.S., 2 Grosvenor St.
1857 Sturrock, John, jun., 3 Queen's Crescent, Newington
1868 Sutter, Archibald, C.E., 9 Manor Pl.
1846 *Swan, Prof. Wm., F.R.S.E., St Andrews
1858 Swann, J. R., builder, 21 Leith Walk
1866 Syme, F. D., 14 Great King Street

1858 Taplin, Thomas, M.D.
1862 *Tawse, John Wardrobe, W.S., 49 Queen Street
1851 *Tennant, Charles, St Rollox, Glasgow
1851 *Tennant, John, St Rollox, Glasgow
1860 Thomson, Alex., teacher, 5-A George Square
1860 *Thomson, Charles W., C.A., 9 Blenheim Place
1863 *Thomson, R. W., C.E., F.R.S.E., 3 Moray Place, *President*
1839 *Thomson, W. T., F.R.S.E., 3 George Street
1858 *Tod, James, advocate, 56 Northumberland Street
1861 Tod, James, engraver, 3 St James' Square
1856 Tod, John, engineer, 29 Leith Walk
1846 *Trevelyan, Arthur, of Pencaitland, Tyneholm, Tranent
1840 *Trevelyan, Sir Walter C., Bart., F.R.S.E., Wallington, Newcastle-on-Tyne
1864 Trotter, Alexander, teacher, 59 George Street
1869 Tunny, James Good, photographer, 93 Princes Street
1840 *Turnbull, W., F.R.S.E., accountant, Royal Bank, 14 Landsdowne Cres.
1822 *Tweeddale, The Most Noble George, Marquis of, K.T., F.R.S.E., Yester House, Gifford

1860 Vallance, George, merchant, 1 Gayfield Square

1840 *Walker, William, surgeon and oculist, 47 Northumberland Street
1859 Wallace, Alex., M.A., assist.-observer, Royal Observatory
1856 Waterston, George, jun., stationer, 56 North Hanover Street
1866 *Watherston, James, builder, 8 Charlotte Place
1866 *Watherston, William, builder, 8 Charlotte Place
1840 *Watson, Henry George, C.A., 123 George Street
1860 *Watson, John Kippen, F.R.S.E., trea. and manager, Edin. Gas-Light Company, 25 Waterloo Place
1850 *Webster, Andrew, S.S.C., 3 Forth Street
1865 Welsh, Richd., coppersmith, 4 Queen's Place, Greenside
1861 Whimster, T., gas-engineer, Perth
1867 Whitehead, John, S.S.C., 15 St Andrew Square
1846 *Whitelaw, James, watchmaker, 30 W. Register Street
1867 Whytock, A., merchant, 9 George Street
1838 *Wilkie, John, of Foulden, Berwick-upon-Tweed.
1851 *Willet, John, C.E., Aberdeen Railway
1864 Wilson, Andrew, dentist, 21 Young Street
1867 Wilson, James T., manufacturing-chemist, Restalrig House

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1858 Wilson, John, coalmaster, South Bantaskine, Falkirk
1859 Wilson, John, F.R.S.E., Professor of Agriculture, College
1868 Wilson, Robert, engineer, Patricroft
1867 Wilson, Thos., teacher, Roberton, by Hawick
1860 Wishart, Edward, merchant, 3 Laverock Bank Terrace, Leith
1861 Wright, James, 13 Ainslie Place
1836 *Wright, Robert, architect, 22 George Square
1859 Wylie, J. S., 5 Viewforth Place
1853 *Young, James, chemical manufacturer, Limefield, West Calder
1859 Young, James, M.D., 36 Castle Street
1861 Younger, Robt., brewer, Croft-an-righ

TOTAL ORDINARY FELLOWS, 398.

The following ORDINARY FELLOWS are ordered to remain, till they return to Scotland, in the following

SUSPENSE LIST.

1859 Richard S. Culley, telegraph-engineer, General Post-Office, London
1868 Henry Dixon, New South Wales
1860 Captain Sir Wm. Hamilton, Bart., Royal Artillery, Simla
1868 N. B. M'Dermott, Jamaica
1862 A. T. Machattie, Ph.D., Ontario Chemical Works, London, Canada West
1870 John Menzies, C.E., Landberis
1846 Mungo Ponton, F.R.S.E., 3 Arlington Villas, Cliton
1854 J. T. Thomson, C.E., Goverment Surveyor, Otago
1854 Dr Daniel Wilson, Professor, Toronto, Canada TOTAL, 9.

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APPENDIX (P.)

NOTE OF THE ORDINARY COURSE OF PROCEDURE FOR THE INFORMATION OF AUTHORS OF COMMUNICATIONS.

1. The Society receives and considers Communications on all subjects connected with the Useful Arts, and on Collateral subjects, from strangers as well as from Members.

2. Communications must be transmitted to the Secretary, with whom, in the first instance, the responsibility of definite acceptance lies.

3. Should the Secretary hesitate as to the acceptance of a Communication he submits it to the Council, and acts on their instructions.

4. Communications intended to be preserved, must be written on foolscap paper, with an inch margin all round; and the accompanying drawings should, if possible, be on the size of imperial drawing paper, with a similar margin.

5. As soon as the Billets intimating any Communication or Report are circulated, the Fellows of the Society are entitled to peruse the same if in the Secretary's hands.

6. In general, though not always, the Society refers the Communication to a Committee.

7. When the Committee's Report is received, intimation is made to the Author, and the Report is open to his inspection.

8. When the Report is read, it is competent for the Society again to discuss the whole subject, to amend or adopt the Report, or to recommit the matter.

9. At the end of the Session a Publication-Committee is appointed to consider the Communications and Reports, and to decide as to whether they should be printed, and how. Plates or Woodcuts to be at the expense of the Author.

10. A Prize-Committee is also appointed to award Prizes to such of the Communications as may appear to be deserving thereof. In making these awards it is understood that originality, ingenuity, and UTILITY are principally considered. The award of the Prize Committee is final, and subject to no remark of approval or disapproval.

11. It is understood that no Member having any interest in any one of the Communications shall be named for the Prize Committee, and as the Secretary is *ex officio* convener thereof, his communications are not submitted for their consideration.

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APPENDIX (Q.)

Proceedings of the Royal Scottish Society of Arts, Session 1871–72.

The Annual General Meeting was held on 13th November 1871,—John Paterson, Esq., Vice-President, in the Chair.

The following Communications were made:—

1. Address by the President, R. W. Thomson, Esq., which, on account of his absence from ill-health, was read by Professor Thomas C. Archer.

On the motion of Mr George Harrison, seconded by Dr Stevenson Macadam, a cordial vote of thanks was accorded to the President, along with a request that he would allow it to appear in the Society's Transactions. (See page 300.)

2. The Report of the Prize Committee was read, and the prizes were delivered by the Vice-President to the successful Communicators.

The following Donations were laid on the table, and thanks voted to the respective Donors:—

1. Proceedings of the Royal Society, No. 129. Presented by the Society.
2. Journal of the Society of Arts, Nos. 972–988. Presented by the Society.
3. Engineering, Nos. 288–304. Presented by the Proprietors.
4. English Mechanic, Nos. 328-344. Presented by the Proprietors.
5. The Artizan, Nos. 7–10, Vol. V. Presented by the Proprietors.
6. Proceedings of the Institution of Mechanical Engineers for April and July 1871. Presented by the Institution.
7. Journal of the Institute of Actuaries, Vol. XVI. Part 4. Presented by the Institute.

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8. Proceedings of the Institution of Great Britain, Vol. VI. Parts 1 and 4, and Journal, No. 7. Presented by the Institution.

9. Minutes of Proceedings of the Institution of Civil Engineers, Vols. XXXI. and XXXII., with Index. Presented by the Institution.

10. Journal of the Scottish Meteorological Society, No. 31. Presented by the Society.

11. Proceedings of the Literary and Philosophical Society of Liverpool, Nos. 23, 24. Presented by the Society.

12. The Canadian Journal, Vol. XIII. No. 2. Presented by the Canadian Institute of Toronto.

13. Transactions of the Institute of Engineers in Scotland, Vol. XIV. Presented by the Institute.

14. Smithsonian Report for 1869.

15. Smithsonian Contributions to Knowledge, Vol. XVII. Presented by the American Government.

16. Congressional Directory.

17. Memoirs of the Boston Society of Natural History. Presented by the Society.

18. Report of the British Association for 1870 (Liverpool). Presented by the Association.

19. Memoirs of David Boswell Reid, M.D., F.R.S.E. Presented by Mr Hugo Reid.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Gentlemen were admitted as Ordinary Fellows:—

1. William Beatson, burgh surveyor, Leith.
2. John G. Winton, C.E., 1 John Street, Portobello.
3. Thomas Craigie Glover, C.E., 29 Hope Terrace, Grange.
4. James M'Kelvie, coal merchant, Haymarket.

III. In terms of Law XV., the Society elected its Office-Bearers for Session 1871–2.

IV. A List of the Office-Bearers, and an Alphabetical List of the Fellows as at 1st November 1871. (See App. U.)

V. A Copy of the Report of the Prize Committee for Session 1870–71; and

VI. A Copy of the "Note of the Society's Ordinary Course of Procedure," agreed to at last meeting, were enclosed with the Billet for the Meeting. (See App. V.)

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Second Meeting—27*th November* 1871.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were read:—

1. On the relative Photogenic or Illuminating Value of Vegetable, Animal, and Mineral Oils, and Coal-Gas, with illustrations. By Stevenson Macadam, Ph.D., F.C.S., F.R.S.E. (See Transactions, p. 325.)

After considerable discussion, in which Messrs John Reid, Miller, Lundy, Cox, John Aitken, the Chairman, and Secretary took part, the paper was remitted to a Committee, consisting of Mr Edward Meldrum, Dr R. M. Ferguson, and Mr Reid, convener.

2. The President read a letter from Professor Archer, drawing attention to a department for *new inventions* in the International Exhibitions.

The following Donations were laid on the table, and thanks voted to the respective Donors:—

1. Journal of the Society of Arts, Nos. 369–981. Presented by the Society.
2. Engineering, Nos. 305–307. Presented by the Proprietors.
3. English Mechanic, Nos. 345–347. Presented by the Proprietors.
4. The Artizan, No. 11, Vol. V. Presented by the Proprietors.
5. Proceedings of the Literary and Philosophical Society, Oct. 1871. Presented by the Society.
6. Transactions of the Institute of Engineers in Scotland, Sess. 1870–71. Presented by the Institute.
7. Journal of the London Institution, No. 8. Presented by the Institution.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. Part III. of Vol. VIII. of the Society's Transactions was laid on the Table.

Third Meeting—11*th December* 1871.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were read:—

1. Circular of the London International Exhibition of 1872, and letter from Professor Archer, Deputy Commissioner for Scotland, were read by the Secretary.

Mr Masson, manager of the North British Railway, gave some information as to the transmission from Scotland of articles for exhibition.

Thanks were returned to Professor Archer and to Mr Masson.

2. On the Analytic Method, and its Influence on Human Progress. By Edward Sang, F.R.S.E.

After some remarks by Mr William Lees, a vote of thanks was accorded for the paper.

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The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 992, 993. Presented by the Society.
2. Engineering, Nos. 308, 309. Presented by the Proprietors.
3. English Mechanic, Nos. 348, 349. Presented by the Proprietors.
4. The Artizan, No. 12, Vol. V. Presented by the Proprietors.
5. Prendergast's Mastery Series (German). Presented by Thomas Prendergast, Esq., late of the Civil Service, at Madras.
6. Patent Office Report for 1868. Vols. I.–IV. Presented by the American Government.
7. Memoirs of the Geological Survey of India, Vols. II., III., IV., and VII.
8. Palæontologica Indica, Vol. III. Nos. 1–8. Presented by order of the Governor-General of India.
9. London International Exhibition: Official Report on Woollen and Worsted Fabrics. By Professor T. C. Archer. Presented by Professor Archer.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Candidates were proposed, balloted for, and admitted as Ordinary Fellows, viz.:—

1. John Mackenzie, M.E., Glasgow.
2. John Aitken, Darroch, Falkirk.

Fourth Meeting—8th January 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communication was made:—

On Water Supply. By Stevenson Macadam, Ph.D., F.C.S., F.R.S.E., and illustrated by numerous specimens. (See Transactions, p. 343.)

A long discussion then ensued.

Mr Alexander Leslie remarked that one very important thing regarding water supply was far too often overlooked. Great care was generally taken to select as a source of supply a locality yielding a quality of water which was unexceptionable, both as regards saline and organic constituents, but after having been brought in and distributed to the population, it was subjected to treatment which rendered useless all the care formerly bestowed on it. He referred specially to the very objectionable practice which existed of placing cisterns containing water for domestic purposes both above and below water-closets—in the one case the absorbing power of the water taking up whatever foul air and gases might be floating in the closet, and in the other subjecting it to the chance of being polluted by the downward passage of foul water escaping from a faulty apparatus in the floor above—and in almost every case the cistern is situated in a place very difficult of being reached, and therefore very

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difficult to clean, a precaution which, instead of being done once a year, if so often, should be repeated, if possible, every month. With regard to the amount of contamination in water, he was by no means prepared to admit that water derived from what is termed highly manured fields is inferior to that flowing off pasture land covered with the droppings of sheep and birds, as he was of opinion that in the process of filtration through arable land the vegetation absorbed a great deal of the objectionable matter, and permitted the pure water to pass into the field drains—for instance, in many towns in England where the water supply is considered excellent, the gathering ground is mostly all under cultivation; and as in the case of the London supply derived from the Thames, the proportion of pasture in the district is very small; and, moreover, the pollution from sewage admixture, although considerable, seems to have little prejudicial effect on its quality. He did not approve, nor put any faith in the experiments made by Dr Macadam on the colour of the different waters by means of porcelain discs, as the very varying circumstances under which the experiments might be carried out render reliance on them impossible—the time of day, the relative position of the sun, the state of the weather, whether calm or windy, and the proximity or the reverse of high hills, and many other causes which cannot be the same, or even similar, in the different reservoirs and lakes in which the observations were made, render it necessary to adopt other means in order to detect the real difference between the shades of the various waters selected for examination. And, in conclusion, he was of opinion that the supposed benefits to be derived for permitting small driblets of water to be continually running in the drains, which is the result of faulty and wasting apparatus, was a mistake, and if the total quantity daily wasted in this manner was used to flush the drains suddenly a much greater advantage would be obtained.

Mr Alexander Gowan said that Dr Macadam in his paper had referred so distinctly to the question of good drainage, that he felt constrained to make the following remarks, illustrative of his experience at Morningside. In one or two villas there he found that where the air was contaminated with bad gas, the evil arose entirely from defective drainage. The present system of drainage was good enough, if the construction of pipes, &c., was properly carried out; but in the above-mentioned cases it was found that leaden cesspools had been constructed without being sufficiently curved to retain the requisite quantity of water, consequently a vacuum was left large enough to fill the house with bad air from the drain. No sooner was a properly constructed cesspool introduced, than the evil was remedied. The cesspools alluded to were under water-closets and wash-hand basins. Again, upon examination of the tile drains, he found that people were living above a foundation completely saturated with foul water escaping from the imperfectly joined pipes. On opening up the ground it was found that these pipes in most cases have fallen an inch apart from each other, allowing the escape of foul water and bad effluvia. The error in laying these pipes at first had, of course, been that the beddage beneath was improper and unfit to support them in a uniform position. Therefore, in order to

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have effective drainage, he recommended—first, that attention be directed to the fitting up of all leaden pipes in the interior of houses, particularly the cesspools; secondly, the proper laying of tile drains in connection with the main drain, which could be done by laying the pipes on a narrow strip of flagstone, thus keeping them in a uniform position—the joints to be fitted with the best Portland cement; thirdly, he advocated the flushing of drains as most essential; and fourthly, he urged that the local authorities should appoint an inspector of drains, at a good salary, whose duty it should be to examine all drains before they are covered up, and to give a certificate that they are properly jointed and laid down.

Messrs S. M'Glashan, John Reid, and E. Sang also took part in the discussion; after which it was moved by Mr Leslie that the discussion be adjourned, and by Mr Reid that Dr Macadam's paper be printed and circulated among the Members. Both of these motions were agreed to.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 994–996. Presented by the Society.
2. Engineering, Nos. 310–312. Presented by the Proprietors.
3. English Mechanic, Nos. 350–353. Presented by the Proprietors.
4. Meteorological Society's Journal, No. 32. Presented by the Society.
5. Proceedings of the Royal Society, No. 130. Presented by the Society.
6. Journal of the London Institute, No. 9. Presented by the Institution.
7. Proceedings of the Literary and Philosophical Society of Manchester. Presented by the Society.
8. Transactions of the Institution of Engineers and Shipbuilders in Scotland. Presented by the Institution.

PRIVATE BUSINESS.

The Minutes of last Meeting were read and confirmed.

Fifth Meeting—22*d January* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were made:—

1. Report of Committee on Dr Stevenson Macadam's Paper on the Illuminating Powers of Oils and Gas (Mr Reid, convener), was read and adopted.

2. On a New Tool-holder for the Slide-rest, by Edward Elmslie Sang, C.E., was read, and, after a few remarks by Mr Miller, was referred to a Committee, consisting of Mr Miller, Mr W. Marshall, and Professor Jenkin, convener. (See Transactions, p. 373.)

3. On the Water Supply of Berwick, by Alexander Leslie, C.E., was read, and illustrated by Drawings. After a discussion, in which Dr

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Macadam, Mr W Marshall, the Secretary, Professor Jenkin, Mr M'Glashan, and Mr Reid took part, thanks were awarded to Mr Leslie, and the paper was ordered to be printed for circulation. (See Transactions, p. 363.)

The following Donations were laid on the table, and thanks voted to the Donors :—

1. Journal of the Society of Arts, Nos. 977–999. Presented by the Society.
2. Engineering, Nos. 313–315. Presented by the Proprietors.
3. English Mechanic, Nos. 354, 355. Presented by the Proprietors.
4. The Artizan, No. 1, Vol. VI. Presented by the Proprietors.
5. Proceedings of the Institution of Mechanical Engineers. Presented by the Institution.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. In terms of Law XX., the Treasurer's books were laid on the table, and a Committee, composed of Messrs Tawse, Rainie, and Dickson, were appointed to audit the same and to report.

Sixth Meeting—12*th February* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were made :—

1. On Colour and Colour Sensation. By John Aitken, Darroch, Falkirk. Illustrated by numerous Experiments. (See Transactions, p. 375.)

The discussion on this paper was delayed until the second part shall have been read.

It was agreed that the two following communications be held as part of the discussion on Water Supply.

2. Notes regarding the Construction of Sewerage and Sanitary Apparatus. By John Paterson, C.E. (See Transactions, p. 419.)
3. Sanitary Liftings. By John G. Winton, C.E.
4. The discussion on Dr Macadam's paper on Water Supply was resumed.

Councillor Gowans said that he supported the scheme for St Mary's Loch, as we needed a full supply of water, and that Edinburgh would never be so healthy as it ought to be until such a supply would be got ; that we needed it for the flushing of drains and other sanitary purposes ; and seeing that Dr Macadam had made out in his paper that the St Mary's Loch water was good, that was the place to go to.

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Messrs M'Glashan, Ramsay, Peters, the Treasurer, Professor Jenkin, Lees, and Alexander Leslie also took part in the discussion, which was again adjourned.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 1000–1002. Presented by the Society.
2. Engineering, Nos. 316–318. Presented by the Proprietors.
3. English Mechanic, Nos. 356–358. Presented by the Proprietors.
4. Proceedings of the Literary and Philosophical Society of Manchester. Vol. XI. No. 8. Presented by the Society.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following candidate was elected an ordinary Fellow:—

John Clapperton, merchant, High Street.

III. A communication was read from the Students of the Edinburgh School of Art, desiring the Society's co-operation in petitioning Parliament for aid, and, on the motion of Dr Macadam, was referred to the Council.

IV. On the motion of Dr Macadam, it was remitted to the Council to prepare a congratulatory Address to the Queen on the recovery of H.R.H. the Prince of Wales.

Seventh Meeting—*26th February* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communication was made:—

1. On the Ingenuity displayed in the Manufacture of German Toys, with Illustrations. By Professor T. C. Archer, Director of the Museum of Science and Art. Professor Archer exhibited numerous specimens of articles in progress and finished. After remarks by Mr Lees, Dr Macadam, and the Secretary, a vote of thanks was heartily accorded to Professor Archer for his interesting communication. (See Transactions, p. 437.)

2. The discussion on Water Supply was resumed, and the following communication from Mr Rowatt was read by Dr Macadam:—

In the previous discussion of this question, reference was made to other towns which had a much smaller supply of water than Edinburgh, and yet appeared to have enough for all purposes. Constantinople was named as one. The argument based on Constantinople is too far-fetched for me to cope with. I know nothing of its water supply. But I do know something of Norwich, which was also referred to. I wrote to a highly respectable firm in that city, asking, among other things, if they could explain

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how the inhabitants of Norwich could do with only 15½ gallons of water per head per day, while other towns in England required so very much more. The following is their reply :—"We think that a large number of houses, especially suburban ones, are supplied by private pumps. Good spring water is obtained at a moderate depth. We believe also, that in lower and old parts of the city there are a large number of pumps in the courts and yards which supply the inhabitants with water not of first-rate quality. There is a general feeling here that the water charge is too high, so that in building new houses wells are sunk." This statement fully explains how Norwich has nominally been supplied with 15½ gallons of water per head, and "*accounts for the milk in the cocoa nut.*" So far as one can judge, the Water Company in Norwich does not appear to supply one-third of the water required there. The engineer of the Norwich Water Company was examined before the committee of the House of Lords against the St Mary's Loch Bill, and it is understood that his evidence had great weight with that committee. I submit, that if these facts, which I have given on the authority of highly respectable parties in Norwich, had been laid before their lordships alongside of the evidence of that engineer, it would have entirely neutralised its influence on their lordships' minds.

The two main grounds on which the Lords' Committee threw out the water bill were *the great waste of water and the abundant supply on the Pentland Hills*, as proved by the engineers who gave evidence against the bill. With regard to the waste of water at Glencorse, proved by these gentlemen, Mr Leslie, in his report, says in his own modest way, "There has been some mistake in the computed overflow from Glencorse, which has been stated to be 242,500,000 feet per annum, or considerably more than the whole of both the water taken to Edinburgh and that required for compensation, and would represent an actual rainfall of 47 in., and an available fall of 33 in., which is much beyond what it actually is." If the members of committee believed that there was more waste of water at Glencorse reservoir than the entire water that flows into it, we need not wonder that the bill was thrown out. Mr Leslie very clearly exposes the character of the evidence which led to this result. With regard to an ample supply being had from the Pentlands, Mr Leslie is equally explicit. Any one who has intelligently read his report must be satisfied that all hope of that may be for ever abandoned. Now if Mr Leslie's report may be relied on, and the testimony from Norwich be believed, then I think it must be admitted that the St Mary's bill was thrown out on the most hollow, worthless evidence ever laid before any tribunal. In this case it happened to be a committee of the highest tribunal of this or any country. A proposal was made in the Water Trust lately to expend L.500 in bringing the Norwich engineer to Edinburgh, for the purpose of introducing into this city the system of the model water company at Norwich. Before this is done, it might be well to know a little more of the details of that company's management. I now quote some of their charges, from an official document signed by the chairman of the company :—Houses under L.5 of rent are charged 4s. 4d. per annum, or on an average above one shilling

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per L., from L.5 and under L.100, the rate is one shilling per L., warehouses one-half of this rate. Suppose the rent of a house is L.99, the charge is L.4, 19s.; if there is a water-closet and bath in the house, 20s. extra is charged. Each water-closet must have a cistern or boot for preventing waste, which, according to Messrs Piper & Theobald's statement, costs when fitted up about L.4, done of course at the owner's expense. How would owners of house property like to pay L.4 for every water-closet in their house? If there is a green-house attached, say 10 yards by 6—quite a small one—there is an additional charge of 20s.; and if there is a garden of an eighth of an acre, 8s. more—in all L.7, 7s.; while in Edinburgh for a similar house we pay only L.2, 17s. 9d., or little more than one-third. There are a number of other charges I might refer to, but will only name one more. The cost of watering the streets is 2d. per square yard per quarter, and as two quarters of the year must be embraced in street watering, the rate is 4d. per square yard. That we may form some idea of what the city of Edinburgh would have to pay for watering the streets at this rate, let me state that the area of George Street, and from the Haymarket to Pilrig, along with the direct line from the Post-Office to Minto Street, as given me by the burgh engineer, is 169,999 yards. For watering these three stretches of streets we would have to pay the nice little sum of L.2833, 6s. 4d.; and these are but a small portion of the streets requiring to be watered. I rather think that the citizens of Edinburgh will be as ready to oppose the adoption of this model town's rates as they were to oppose the St Mary's scheme. If we had as full information as to the details of the supply of water to Constantinople as we have of Norwich, it is possible we might find the argument for small supply drawn from it as valueless as the one based on Norwich.

Whilst speaking on the amount of water used, I may state that the Terraces round Calton Hill are at present using 51 gallons per head per day; Stafford Street and William Street, 31; Jamaica Street, 20; and Viewcraig Row, between 12 and 13. These districts are all tested by meters; the apparatus has been carefully examined to see that there is no waste, and in none of them is any water used for manufacturing purposes.

I cannot understand why such an earnest desire should be shown, to limit Edinburgh to a minimum quantity of water, when beyond all question an abundant supply of it is the greatest earthly blessing a large city can enjoy. If those gentlemen who have so persistently shewn this desire, would only come down with me some morning before the scavengers commence their work, and see the filth and abomination of every kind pitched over the windows into closes in the High Street and Canongate, they would be satisfied that scavengers cannot clean these closes with besoms and shovels. They remove the greater portion, and spread the remainder over a broader surface. They would see for themselves that nothing but a full flood of water could entirely carry away all offensive matter, and leave the place sweet and clean. I do not know any town that would require so much water as Edinburgh; it has so many narrow closes, high houses, and steep inclines; and I believe I am speaking the

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truth when I say that it would require more for sanitary purposes than the entire quantity it receives for all purposes. One great advantage of having an abundance of water would be the ease with which we could clean and water our streets. I showed the Cleaning and Lighting Committee a machine something like a fire reel, having a water-tight centre compartment, and a gutta-percha hose; with this machine two men could wash down the pavement in less time than it would take ten men to sweep it. They could also water Princes Street in less time than ten horses and water butts would do; indeed, it would be an easy matter to overtake the watering of the entire streets in the city. With an abundance of water we might have that magnificent work of art, the Ross fountain continually flowing—a fountain without water is a misnomer,—and if the West Meadows were laid out as a people's flower garden, we might there have artificial ponds, with water plants, water fowls, &c., such as many smaller towns than Edinburgh have.

No subject has occupied more attention lately than the removal of noxious gases from sewers. For some time back there have been on an average two patents taken out every month for ventilating sewers. I suppose it will be admitted that not one of them has been found efficient. One patent has been taken out a few days ago by a townsman, which we are likely soon to hear more of; it may turn out effective, but meanwhile why not flush them with water, by the aid of a sluice, put in say 50 yards from the top of the drain? Fill this part of the sewer from the fire plug, then draw the sluice, and the flood of water will carry all noxious gases and everything obnoxious right away to Inchkeith. This would be cheaper and more effective than anything that has yet been tried that I know of.

There is one great benefit an ample supply of water would confer on the citizens of Edinburgh that I think has not been brought so prominently out as it might have been. I refer to the important fact that every L.3000 worth (speaking in round figures) of water sold by meter reduces the water rate 1d. per pound. I know many applications have been made for water for manufacturing purposes, but as no guarantee of supply could be given, the works did not go on. Mr Widnell, when obliged to remove his carpet factory from Lasswade, took off a feu, intending to establish it in the suburbs of Edinburgh; but as the water company could not guarantee him a constant supply of water, he had to go to Roslin. He would have required a very large quantity for washing his wools, &c., at least L.1500 worth. I am informed on unquestionable authority that Mr MacMurray intended building a paper-mill on his own property in Leith Walk. He reckoned on sinking a well and pumping so much water, and still would have required a very large quantity in addition, but like Mr Widnell, for want of water he had to go elsewhere. These are only two instances out of very many similar applications. I do honestly believe that in five years after the bringing in an abundant supply of water the rates might be reduced one-half by the sale for manufacturing purposes. Glasgow has already reduced the rates there from 1s. 4d. to 8d.

A letter from Mr Smith was read by the Secretary.

Mr John J. Lundy said that Dr Macadam in his paper on "Water

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Supply," entered more into the subject of quality than of quantity, and more into the chemistry or purity of the water than into the procuring, distributing, or stoppage of waste. Nor did he enter upon the great subject of the quantity required per head of the population, or the necessity of a greater supply being required, or, if there be such a necessity of a greater supply, whence it was to be procured. Having taken some small share in opposition to the St Mary's scheme, he might be allowed to state that he believed there was no necessity for several generations for the people of Edinburgh and Leith to search for any larger supply than the present locality of the Pentlands, because he believed there was already sufficient water, if the separate and better system of sewerage were adopted, namely, to have one drain for sewage and the other for the rain water. He considered that the larger the quantity of water the quicker the decomposition and putrefaction of sewage ensued with its evolution of sewage gas, and consequently the present large sewers were wrong upon principle. Professor Jenkin said the other night that salt water was bad for sewers, and as it had been abandoned by some first-class steamers which now only use condensed water for their water-closets, he (Professor Jenkin) said "there was nothing more to be said about it." Mr Winton spoke of salt water "pickling" the sewers, and he agreed with Mr Winton, whilst deferentially disagreeing with Professor Jenkin, as he gave the Society no reasons why salt water was bad, except that it would make an "intolerable stench." So far the learned Professor may be and no doubt was correct, as it would raise a stench in the present sewers at first; but flushing with fresh water did the same thing, yet he did not tell them he was sure that were salt water used continuously it would continue to do so. The stench was caused by contact with matter already putrefied; but, if salt water were used before the fæces or urine were decomposed, they would be, as Mr Winton said, "pickled," and reach the outlet of the sewer at the Firth of Forth before decomposition had set in. Mr Ramsay had said there was only one use for salt water, namely, to water the streets, but as Mr Leslie had shown in a paper upon the water supply of Berwick, the cost of pumping 1000 gallons of water 100 feet high need not be more than one-third of a penny, or that pumping would cost about ½d. to ·631 of a penny per horse power per hour, an easy calculation could be made as the cost of pumping sea-water—plus the interest on the piping not only for the one purpose of watering our streets, but also for baths (public and private), flushing our sewers, and some manufacturing operations where salt water could be used, such as cooling and condensing, so that large quantities of fresh water could be liberated for domestic use, our streets be less dirty, our sewers almost, if not entirely free from sewage gas, and the benefit of salt-water baths in our houses—because if salt water could be had for say 3d. per 1000 gallons, few large houses would be without it laid on to their baths and water-closets. To prevent waste, and to procure the certainty of every house having good water fittings, every consumer of fresh water should be charged by meter, so as to make every householder look as sharply after his water bill and fittings as he now does after his gas. Meters, and not rents, are the only rational mode to charge for water, whether

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salt or fresh; people ought to pay, and did pay for everything, except water by quantity. Why water should be an exception, he said, he did not know, nor did any one else. It was not like air, which costs nothing, and of which each individual can only consume a given quantity, and of which there is an unlimited supply without cost; but water was limited in quantity, and costly according to locality; and, as they were all well aware, some people consume and waste far more than others, they ought to pay for it in proportion. Mr Winton's turbine theory of ventilation might thus be reduced to practice, and Mr Paterson's idea carried out of flushing sewers once a week from valves, or, as he desired, tanks 100 yards apart; only, he would prefer, instead of fixed flushing tanks, to have movable tanks like those in Leith, or by valves placed upon the salt-water pipes in certain most approved localities, to open at a given pressure, so that if the pumping engines were kept pumping night and day to keep up that pressure; when the salt water was not being used for other purposes the valves would open and flush the sewers intermittently by day, and continuously all night, whilst if at certain intervals there were air-shafts near the flushing valves, *where* the water could work turbines driving fanners at their base, when the valves opened at night more especially would the barometric pressure be taken off the sewers and household fittings, and even defective fittings become ventilators of the vitiated air from the dwellings into the sewers, instead of outlets of foul gas from the sewers into the houses, dealing disease and death as they do, when the body during sleep has the least amount of vital power to resist it. Mr Paterson had spoken of the proper place to begin the ventilation of sewers as at the lower level. By this he understood him to mean, whether ventilation by currents caused by furnaces and shafts, by fanners driven by steam or by turbines, or simple air shafts, whichever might be adopted. At Croydon, Mr Latham and Dr Carpenter found that the lower end was the better to commence at, and epidemic and endemic disease disappeared as they went upwards, whilst it was safer for the health of the workmen employed in their construction. At Croydon also was adopted dry charcoal filters, and he would advise any of the Fellows of the Society interested in these sanitary subjects, when in London to make a run over to Croydon to see the sanitary arrangements of that place, as they are well worth the time and trouble. The allaying of dust, he said, was a great necessity. Dust damaged immense amounts of goods, and to the shopkeepers was a great annual loss, whilst the large extra amount of water used in cleaning their houses, their clothes, and their persons, the quantity was almost incalculable. This dust was a source of disease, and a great aid to the spread of epidemics. When they recollected of what this dust was composed there was no doubt of it. The dust of our streets was only the *silica* from causeway and paving stones ground down by the vehicles and foot-passengers, mixed with ground leather and iron from the shoes of men and horses, with horse dung and human excrement, which the traffic on ordinary calm days in narrow bustling streets, or in wider ones by simple aid of the sun's rays, just rose to the level of our mouths and nostrils, necessarily damaging the very air we breathe when walking, whilst it rose and

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spread all over, and even enters our highest windows in windy weather. This dust must contain the germs of disease, and so spread epidemics in towns like those of Scotland, where every house has not a dust bin, water-closet, or privy, where most of the poorest class of children required, and were made to do all the offices of nature in the streets, and where ash backets were an institution, but specially in localities where ash backets were a luxury unknown or generally too small for a poor family, so that the contents are often emptied on to the street to blow about. Mr Sidebotham, the analytical chemist of Manchester, discovered that a great portion of the dust in the railway carriage he was riding in was iron abraded from the wheels and rails, what then were the abominations in the dust of our streets? Could anything than the destruction of our shopkeepers' wares, the extra quantity of water required for our houses, clothes, and persons, and the necessity to allay the dust of our streets, to purify the atmosphere we breathe, speak louder to prove the necessity of our thoroughfares at all events being kept damp, and if damp, then by the cheaper salt sea water instead of damp from the dearer fresh water—the sea water dampness being less injurious to health than that from fresh water, either of which would be more than counteracted by a purer atmosphere. Hence he believed if there were more storage ground prepared in the Pentlands, a scientific distribution, water meters as the best preventive of waste, and salt water provided so as to take proper advantages of our position as a seaside population, we can have plenty of pure water from the Pentlands, purer air, and no sewage poisoning gas, all for one-tenth of the cost of the St Mary's Loch scheme. Eight or nine years ago he recommended the Town Council of Leith to ventilate the Leith sewers into the Gas Work chimney and other manufacturers' chimneys there, but through the report of Messrs Stevenson it was not adopted. He was glad to find, however, little Portobello, under the advice of Dr Macadam, had last November carried out the idea, and proved it correct. Had Leith adopted it eight years ago, it would have saved many hundreds of lives in Leith, and possibly a larger number in Edinburgh, as he believed it would have produced that negative barometrical pressure that might have saved a great deal of the fevers and small-pox which have carried off so many of our population. Mr Gowan's idea of a double trap, he said, he had adopted five or six yeas ago, as his house, situated at the head of a sewer, was constantly invaded by sewage gas. Since he had adopted the double trap, he found when one was flowing the other acted as a check, and that the ordinary water luted trap, thought to be so perfect, was only perfect when double, and scarcely then, unless ventilated from the top or air-part of the one nearest the inlet of the house. There was one remark he would make regarding Mr Peters' statement as to sewage gas acting upon the lead pipes of water-closets. If it were so, then it proved the necessity of ventilation of our sewers, and also the necessity of greater attention to the quality and purity of the lead used for sanitary purposes, but especially that used for water pipes for domestic use. There were two kinds of lead known to manufacturers—one as hard lead, and the other as soft. He had never heard of this part of the subject being broached before, regarding

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water pipes and cisterns, but to chemical manufacturers, like himself, it was well known to be very important. For instance, a vitriol chamber when made of one kind of lead lasts more than twice as long as the other. He would suggest that careful experiments be made as to the action of water and also of sewage gas upon both, and that plumbers be thereby given the necessary information they were now deficient in as to which was the best to use, and how to distinguish them. Then there was the possibility of galvanic action taking place between the lead and the solder at the places where the joints were made for water supply, as well as in water-closet pipes, and which if it does must more quickly lead to the rapid destruction of our underground fittings than we are perhaps aware of. He would suggest that to prevent that, *new* lead only should be used for water piping and sanitary purposes, and not old lead, which was often mixed with the solder of old joints, composition gas-tubing, &c., and also that all joints be compulsorily made only by being burnt together with the oxyhydrogen blow-pipe instead of the soldering bolt and solder, which he felt sure would some day become a thing of the past in such cases, as it was with the joining of all lead connections in chemical works.

Councillor Lees said it had been mentioned to him that in Regent Terrace, and in the terraces along the ridge of the Calton Hill, the consumption of water was 60 gallons per head in the 24 hours; but he was afterwards told that that was a special circumstance, and that that quantity was not, in reality, being consumed. In Regent Terrace two causes of waste were discovered, and in the other terraces other causes of waste would probably be found to exist. He had not the slightest doubt that there was no place in Edinburgh where people were legitimately and fairly using 60 gallons per head in the 24 hours.

Mr Edward Sang said the first thing which they had to consider, after bringing water into a town, was the mode of its distribution. Our present mode came to this, that every householder had an opportunity of wasting as much water as he liked. That was really the state of the case. He had made an experiment in his own house, and he would tell the meeting the result. He was two storeys up, in George Street, and he had found that it was the easiest thing in the world to waste a hundred times the quantity of water which he used, and to waste it without his neighbours knowing anything about it. Lower down than he was he knew that a waste had been going on, and, although he had no means of measuring it, he was quite sure that 150 supplies were run away in the house in question for days and days—that was to say, that one person was wasting as much water as would have supplied 150 times his family. It was the idea of the supply of water being unlimited that had led to this waste. The moment they came to find that the supply was really limited, they must set themselves to work to curb the power of wasting; and he was glad to see that the Water Trustees were at present doing that in a kind of way. He thought there was no just plan of allocating the price of the importation of water into towns but that of charging by measure; and with regard to the quality of water, the difficulties of determining the limits of unwholesomeness were exceedingly great.

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Mr John Reid said, that water collected from land surfaces and rainfall while flowing towards the artificial reservoirs in the Pentland Hills, carried with it a very large quantity of mud and silt. The dimensions of even the largest of these reservoirs are so limited as compared with the rate of outflow, that the silt has not sufficient time to settle down until it is drawn off by the pipes. The process of artificial filtration is often ineffective and always expensive. In wet weather this is made apparent by the turbid and muddy condition in which the water reaches the consumers in Edinburgh. The *time* required to permit fine particles of even the heaviest rocky matter to sink in water is little affected by the specific gravity or density of the original material. Mr Reid here explained this statement, by showing that the relation subsisting between the *absolute weight* of any solid substance or figure, and its outer bounding surfaces, alters prodigiously as the body is diminished in size. For example, take a cube of two inches, whose weight is eight ounces; it has an outer surface of twenty-four square inches, while a cube of one inch, same substance, will weigh one ounce, and have an outer surface of six square inches. In the smaller cube, the relative area of its surface as compared with its absolute weight, is therefore clearly double that of the larger cube. These relations, when applied to a gold *sovereign* and the *same weight* of gold leaf will farther illustrate the fact.

It is therefore obvious that as the particles of any heavy body are diminished in size—or rather in *weight*—the relative boundary surfaces may increase infinitely.

It is this enormous relative *extension of surface*, as compared to the actual *weight* of very small particles sinking by gravitation in water, and the friction these surfaces encounter by their contact with the fluid, which retards their descent so much, as to require days or *weeks* to reach and settle at the bottom. This circumstance, he said, explained the remarkable clearness of the waters supplying such towns as Glasgow, Inverness, and St Petersburg, which flow out of *large* and deep natural stores of water like those of Loch Katrine, Loch Ness, and Lake Ladoga. These immense bodies of water afford perfect *stillness*, ample *space*, and sufficient *time* for mud to settle down.

St Mary's Loch seems to present the requisite conditions for furnishing similarly clear water. The quality and fitness otherwise, notwithstanding much asserted to the contrary, he thought satisfactorily proved, as well as its *abundance* for the wants of Edinburgh for generations to come. Giving every allowance in favour of the various competing schemes, he was of opinion that St Mary's Loch was beyond comparison the best available source from whence the large and increasing population can rely for obtaining a full and satisfactory water supply.

After remarks by Mr A. Leslie, Professor Jenkin, Mr Paterson (who exhibited drawings of traps for preventing smell), Mr Reid, Mr Gowans, and Mr Brebner, the discussion was still further adjourned.

The following Donations were laid on the table, and thanks voted to the Donors:—

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1. Journal of the Society of Arts, Nos. 1003, 1004. Presented by the Society.
2. Engineering, Nos. 319, 320. Presented by the Proprietors.
3. English Mechanic, Nos. 359, 360. Presented by the Proprietors.
4. Proceedings of the Literary and Philosophical Society of Manchester, Vol. XI. No. 9. Presented by the Society.
5. Journal of the London Institution, Vol. II. No. 11. Presented by the Institution.
6. Proceedings of the Institution of Mechanical Engineers, October 1871. Presented by the Institution.
7. Journal of the Institute of Actuaries, No. 86. Presented by the Institute.

PRIVATE BUSINESS.

I. The Minutes of the previous Meeting were read and confirmed.

II. The following Candidates were admitted as Ordinary Fellows:—

1. James Morrison, Sub-Convener of City of Glasgow. Improvement Trust, 102 Renfield Street.
2. Thomas Hall, painter, 1 Queen Street.
3. John Macrae, C.E., 107 Princes Street.

III. The Secretary read the following Addresses, which had been prepared by the Council, and transmitted to Her Majesty and to H.R.H. the Prince of Wales:—

To the Queen's Most Excellent Majesty—

The humble Address of the Royal Scottish Society of Arts.—We, the President, Council, and Fellows of the Royal Scottish Society of Arts, desire to approach your Majesty with our heartfelt congratulations on the recovery of His Royal Highness the Prince of Wales from his late dangerous illness. We deeply sympathised with your Majesty and the Princess of Wales, during the sad and anxious hours of that illness now happily passed away, and we earnestly pray that His Royal Highness' health may soon be completely restored, and that His Royal Highness may be preserved a comfort to your Majesty and to Her Royal Highness the Princess of Wales for many years to come.

Sealed with the seal, and signed on behalf of the Society, by the President, Secretary, and Treasurer.

Sir,—I am directed to request that you will be good enough to lay before his Royal Highness the Prince of Wales the following resolution passed by the Council of this Society at its last meeting. Resolved—"That the President, Council, and Fellows desire to record the deep satisfaction with which they have learned that the recovery of His Royal Highness the Prince of Wales from his dangerous illness may now be considered as

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established, and desire to express their hearty congratulations thereon to Their Royal Highnesses the Prince and Princess of Wales."

Signed by the Secretary.

To General Sir William Knollys, K.C.B.,
Marlborough House, London.

Eighth Meeting—11*th March* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were made:—

1. On a Simple Way of showing the Motion of Waves on the Surface of a Liquid, by Robert M. Ferguson, Ph.D., F.R.S.E., was read, and illustrated by help of the Lime-Light. After a few remarks by Mr Lees and Mr Sang, a cordial vote of thanks was accorded to Dr Ferguson for his interesting communication. (See Transactions, p. 432.)

2. The discussion on Water Supply was then resumed.

Mr George Romanes said,—I take it to be admitted that our present water supply, which consists principally of spring water, is superior in quality to the water of the other sources which had been proposed as available for Edinburgh; for if it is not, it can be exchanged at once for a water almost identical with any one of them, by using more of the reservoir water, and letting part or the whole of the springs go for compensation. I am decidedly of opinion that it is better to have a moderate supply of this undoubtedly good water, than a superabundant supply of water of an inferior quality. The reason which seems most to influence public opinion in favour of a very large supply is that it is thought best for the sewers. I admit that the large supply is to some very small extent better for the sewers; but these can be properly made to suit any given quantity of water; and if they are not properly made, it seems to me to be infinitely better to improve their construction, than to attempt a very questionable and partial remedy, by diluting the sewage at an enormous expense.

Next comes the question, Can this moderate supply be distributed in such a way as to enable all to have their fair share, without using any undesirably expensive apparatus, or causing undue restrictions on the quantity used? I am quite satisfied that this can be done in the following way:—

Let the size of all ball-taps be diminished to a fraction of what they are at present, so that they shall only be able to discharge about two or three times a fair allowance in the twenty-four hours. The quantity can be adjusted with sufficient accuracy by means of a small cock on each house supply pipe, under the control of the water-officers. The amount to which the supply could be restricted in any particular case, without inconvenience, would depend on the maximum rate of consumpt and the size of the cistern; but a few experiments I have made, on days of maximum consumpt, in two houses, have led me to believe that a maximum inflow to the cisterns at the rate of about 60 gallons per head per

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day would, in most cases, be quite sufficient. In cases where baths are frequently used on washing days, that rate of inflow would probably necessitate a considerable amount of cistern room, but those who can afford this luxury would find a supplemental cistern a very slight additional expense.

I shall now sum up what I believe would be the effects of restricting each consumer's power over his water supply as above suggested.

1. Gross cases of waste would be rendered impossible, as each consumer's power of wasting would be reduced to *a fiftieth*, or in some cases *even a hundredth part* of what it is at present.
2. Ball-taps being small would require only a small force to keep them closed; there would thus be greatly less risk of waste through their getting out of order, which they do so often at present, and there would be less harm done if they were to get out of order.
3. House supply pipes, ball-taps, and waste pipes might be all made much smaller and cheaper.
4. A great number of houses on different flats could be fairly supplied by a single pipe, without the under flat having, as at present, command of all the others.
5. An almost equable pressure would be maintained in the street pipes, on account of the more constant flow through them.
6. Should it become necessary, in time of excessive drought, to have the supply intermittent, the distribution would be far more fairly effected, as those cisterns which are high above the street would be filling at the same time as the lower ones.
7. There would be no undue restriction on the quantity used.
8. The house pipes would be much less liable to freeze, on account of a more constant flow through them.

In conclusion, I may remark that there is nothing objectionable in the judicious use of strictures; although it has been proved to be a bad plan to use them in the wrong way, and, above all, to conceal the fact that they were used.

The following gentlemen also took part in the discussion, viz.:—Messrs Proctor, Gowans, Lundy, Sutter, and Rowatt.

Dr Stevenson Macadam then replied on the whole discussion, and said he was glad that so many Fellows of the Society and others had spoken on the subject of water supply, because he felt certain that the thorough discussion of this important question must ultimately lead to the good of the city. The first division of the paper was on the quantity of water required, and necessarily great differences of opinion had been expressed during the discussion, but there was one thing certain, that we did not at present get the quantity we absolutely required for sanitary measures. A general statement had been made that there was an abundance of water for the flushing of drains and common sewers, but no one had ventured to explain how it was that with diminished water supply for years back, we could get that extra quantity which ought to be at hand for the periodic flushing of the drains and sewers. The condition of the Edinburgh drainage is not the best. Accumulations of fœtid matter in the bed, and

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on the sides of the main sewers are not unfrequent, and such are constantly evolving noxious gases. It is true that fresh sewage is comparatively harmless, and if the ordinary current of water carried everything with it to the outlets, then the flushing of the drains would not be of so much importance. But it is otherwise, and offensive unwholesome gases are being constantly evolved. Many of the larger, and even smaller sewers, are old-built drains, where the lime has been much eaten away by the run of sewage and are leaking, and there are numerous cesspools connected with modern as well as old houses; so that this labyrinth of sewers, with innumerable house connections, ought to be kept as sweet as possible. Ventilation of the smaller drains by pipes, and the larger sewers by shafts leading to furnaces would undoubtedly do much good, and ought to be carried out in numerous places; but the very necessity for ventilation admitted the existence of the evil; and we ought by periodic flushing to endeavour to cleanse the sewers, and thus remove the cause of the evil. The so-called *waste* of water which is assumed to take place does good, not so much by removing the sedimentary matter in the drains, as by supplying air dissolved therein, to oxidise or burn up the noxious gases as they are being evolved. The action, therefore, is not so much mechanical as chemical. That the waste water does good in this way is plainly observed from the fact, that the sewage escaping from all our main drains is almost entirely devoid of dissolved oxygen, so that an excess of water in a sanitary point of view has certainly not passed into the sewers. The elaborate inquiry carried on by me in connection with the water of Leith drainage scheme proved that the sewage of Edinburgh was under and not over aerated. People should be encouraged to use water without stint, instead of being discouraged from using it. *Waste* is not a word to use when the sewerage of the city is far from being perfect, or as good as it ought to be, and requires a constant current of water to keep it even in a tolerable condition. It is a mistake to suppose that the larger the quantity of water which was passed into the drain the quicker the putrefaction of sewage took place with its disengagement of sewage gas. The truth is, that the aerated water tends to oxidise or burn up the organic matters, and to render innocuous the putrefactive gases, and hence serves as an opposing and salutary agent in a sanitary point of view.

The fact that in the larger houses the greatest amount of water was consumed per head of the population need not cause surprise. In the smaller houses there are several people to a room, whilst in the larger houses there may be several rooms to each person. More water must, therefore, be employed, even in the cleansing of the rooms, not to speak of greater attention being paid to personal ablutions, and to the washing of clothes, &c. Moreover, the larger houses are those in which the waste is less likely to go on, for there the apparatus is in more perfect order. The introduction of water meters into houses is strongly to be deprecated, because it would lead to the stinting of water for even domestic cleanliness; and the disuse of water, even in part, by individual families, must affect neighbours, and be a public calamity. Neither air nor water—the two great natural sanitary agents—should be placed under such restric-

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tions as would lead to a minimum use of either. Public health and public weal demand freedom of use of both air and water.

The quality of water has also been referred to in the discussion, but there has been little difference of opinion expressed. It is a mistake to suppose that the water now used in Edinburgh is solely "Crawley," or even spring water. No doubt the greater part of what is brought from the north side of the Pentlands is spring water, but a large proportion is drawn from the central ranges of the Pentlands, where the ordinary rainfall, as well as the spring water, is collected. The Glencorse and Logan Lea reservoirs include surface as well as spring water—and taken as a whole, the Pentland water is mixed surface and spring water, and is practically similar in all its properties to what can be obtained from other districts, such as the Lyne, Heriot, Talla, or St Mary's. The doctrine of hard waters being more healthy than soft waters has been virtually abandoned by its adherents, and the foremost advocate of the hard water views has actually certified, after the examination of a sample of "pure aërated fresh water,"—being distilled water with air dissolved therein,—that "it contained a very small proportion of saline matter, which I regard as an advantage, as it approximates the quality of the water to that derived from the best natural sources." No one has expressed the slightest doubt as to the views announced in the paper regarding the vegetable and animal life in natural waters, so that we consider the "water flea" difficulty at rest for the future. A similar remark applies to the question of the action of natural water, either hard or soft, upon lead, where the views expressed have remained unchallenged.

The nature of the gathering-ground for water supply has called for some comment. The drainage from cultivated ground, which is highly manured season after season, is always impregnated, more or less, with the products of decomposing manure; such water cannot be so free from noxious elements as that flowing from pasture land. In fact, instances have occurred where the water from manured fields has proved injurious, and, therefore, such should only be tolerated for domestic supply when it is not possible to obtain purer and better water.

The mode of testing the colour of the water by the porcelain disc or plate has been commented upon. The operator must take the whole circumstances as to weather, sunshine or cloud, smoothness or roughness of water, distance from surface of water, &c., into consideration, and invariably check the results by filling a long and wide glass tube with the water, and looking down through the column of water, having placed a white surface beneath.

The proper keeping of water when once it has been brought to town is of the utmost importance. The position of cisterns above water-closets must lead to the impregnation of the water with foul gases, and tend to unwholesomeness; but the most serious evil is the want of periodic cleansing of the cisterns. Not only does a deposit of sand and clay take place, but more or less organic matter lodges in the cisterns, and very readily tends to the fouling of the water. Every cistern should be cleansed out periodically—say every month, where such is practicable. To enable

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this to be done, the cisterns should be accessible, which in many instances is not the case at present.

Whether the future of the water supply for Edinburgh is to be in the Pentlands, the Heriot, the Lyne, the Talla, or the St Mary's Loch districts, the water from all these sources is good. The St Mary's district has this advantage, that we positively know what can be yielded at all seasons. The worst that has been said is, that the water of the Megget stream, which flows into the St Mary's Loch about the middle, is of a brown tinge during heavy floods; but no one has ever seen the outlet water from St Mary's Loch, as it is flowing into the Yarrow, either brown or unfit for use. In fact, the Loch is a great natural settling and clarifying reservoir, and taking it all in all, it would be difficult to find a better water collecting district, either in the Highlands or in the Lowlands, or one more likely to prove a blessing to a large community.

Dr Macadam's communication was then referred to a Committee, consisting of Mr James T. Wilson, Mr J. J. Lundy, and Dr Ferguson, convener.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of Society of Arts, Nos. 1005, 1006. Presented by the Society.
2. Engineering, Nos. 321, 322. Presented by the Proprietors.
3. English Mechanic, Nos. 361, 362. Presented by the Proprietors.
4. Proceedings of the Literary and Philosophical Society of Manchester, Vol. XI. No. 10. Presented by the Society.
5. Transactions of the Institution of Engineers and Shipbuilders in Scotland. Presented by the Institution.
6. Transactions of the Botanical Society of Edinburgh, Vol. XI. Part I. Presented by the Society.
7. Journal of the Royal Dublin Society, No. 40. Presented by the Society.
8. Scottish Meteorology, from 1856 to 1871. Presented by the Astronomer Royal for Scotland.
9. Sewerage as a Manure. Presented by A. Smith, Esq., C.E., Aberdeen.

PRIVATE BUSINESS.

I. The Minutes of the previous Meeting were read and confirmed.

II. The following Gentlemen were admitted as Ordinary Fellows:—

1. Eneas R. Macdonell of Morar, 7 Coates Crescent.
2. John M'Neil, plumber and brassfounder, 6 Mill Street, Perth.
3. Roderick A. F. S. Coyne, C.E., 123 Princes Street.
4. William Murray, wine merchant, 2 St Andrew Square.
5. J. D. Wormald, W.S., Middleby Street.

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Ninth Meeting—25*th March* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communication was made:—

On the Ferrie Coking Blast Furnace, as in use at the Monkland Iron and Steel Works. By Dr David Gibb, medical officer to the company. Illustrated by help of Diagrams and Specimens.

After a discussion, in which Messrs Cadell, Bouch, Sang, Miller, Simpson of Benhar, W. Marshall, J. Reid, and the President took part, the communication was remitted to a Committee, composed of Messrs T. Bouch, A. Landale, and H. Cadell, convener.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, Nos. 1007, 1008. Presented by the Society.
2. Engineering, Nos. 323, 324. Presented by the Proprietors.
3. English Mechanic, Nos. 363, 364. Presented by the Proprietors.
4. Memoirs of the Geological Survey of India, Palæontologia Indica. Ser. VI. and VII.
5. Records of the Geological Survey of India, Vol. IV. Parts 3 and 4.
6. Observations on the Geology and Zoology of Abyssinia, by W. T. Blandford. Presented by the Indian Government.
7. Proceedings of the Royal Society, No. 131. Presented by the Society.
8. The Canadian Journal, Vol. XIII. No. 3. Presented by the Canadian Institution.
9. On Asbestos as a Steam-Engine Packing, by St John Vincent Day. Presented by Mr Day.

PRIVATE BUSINESS.

I. The Minutes of the previous Meeting were read and confirmed.

II. The following Candidate was elected an Ordinary Fellow:—

Benjamin Hall Blyth, jun., A.M., C.E., 135 George Street.

III. The Report of the Committee appointed to audit the Treasurer's books was read, and the President granted discharge to the Treasurer in terms thereof.

Tenth Meeting—8*th April* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were made:—

1. On the Quadrantal Propeller, by Robert Thomson, engineer, 59 Broughton Street, was read, and illustrated by a Model.

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After some remarks by the Secretary, Mr Miller, and Mr T. Stevenson, the communication was referred to a Committee, consisting of Mr Peebles, Mr A. D. Stewart, and Mr Romanes, convener.

2. Notice of an Intermittent Azimuthal Condensing Light, by Thomas Stevenson, C.E., F.R.S.E., and

3. Notice of Composite Coloured Glass Panes for Lighthouse Lanterns, by Mr Stevenson, were read, and illustrated by Drawings and one of the Panes. (See Transactions, p. 425.)

After a few remarks by Mr Sang, the two communications were remitted to the following Committee:—Professor Swan, Dr Ferguson, and Mr Wm. Lees, convener.

4. Description of a simple Apparatus by which Switches are worked on the Trains at Garriongill, invented and applied by Mr John Scott, colliery manager, by David Landale, M.E., was read, and the working of the apparatus was shown on a model by Mr Scott. (See Transactions, p. 430.)

After some remarks by Messrs Miller, Landale, Sang, and Stevenson, the communication was remitted to a Committee, consisting of Messrs J. Mackenzie, D. Marshall, and Wm. Marshall, convener.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, No. 1009. Presented by the Society.
2. Engineering, Nos. 325, 326. Presented by the Proprietors.
3. English Mechanic, Nos. 365, 366. Presented by the Proprietors.
4. Proceedings of the Royal Society, No. 132. Presented by the Society.
5. Journal of the London Institution, No. 13. Presented by the Institution.
6. Transactions of the Institution of Engineers and Shipbuilders in Scotland, March 1872. Presented by the Institution.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed.

II. The following Candidates were elected Ordinary Fellows:—

1. John Guthrie Smith, advocate, sheriff of Aberdeen and Kincardine, 10 Abercromby Place.
2. Dr David Gibb, medical officer to the Monkland Iron and Steel Company, Rosehill House, Airdrie.

Eleventh Meeting—22*d April* 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Communications were made:—

1. On an Improved Method of Corresponding with Blind Persons, by Robert Meldrum, teacher of the blind, Alloa, was read by Mr Meldrum, who also exhibited his instrument in action.

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After remarks by the Secretary, by Mr Thomas Will (a blind person), the President, and Mr Peebles, the communication was referred to a Committee, composed of Mr Lees, Mr J. K. Watson, and Mr A. Fraser, convener.

2. On the Arrangement of Weights for Accurate Weighing, by Edward Sang, C.E., F.R.S.E., was read, and thanks voted for the communication.

The following Donations were laid on the table, and thanks voted to the Donors:—

1. Journal of the Society of Arts, No. 1010–1012. Presented by the Society.
2. Engineering, Nos. 327, 328. Presented by the Proprietors.
3. English Mechanic, Nos. 367, 368. Presented by the Proprietors.
4. Proceedings of the Institution of Mechanical Engineers, January 1872. Presented by the Institution.
5. On Pressure Logs for Measuring the Speed of Ships. By James R Napier, F.R.S. Presented by Mr Napier.

PRIVATE BUSINESS.

I. The Minutes of last Meeting were read and confirmed

II. The following Candidates were admitted as Ordinary Fellows:—

1. Richard F. Russell, cashier, Uddingston Oil Works, Glasgow.
2. John M'Queen Barr, accountant, Glasgow.

III. In terms of Law XX., the Treasurer laid on the table the List of Members in arrear of their Annual Contributions.

IV. The Council recommended that the Society should authorise the Report of the Jubilee Dinner to be printed along with the Transactions, which recommendation was adopted by the Society.

V. The proposal that the Society should institute examinations in Technical Science was considered, and the recommendation by the Council that the Society appoint a Committee to consider the subject and to report thereon to a special meeting, was agreed to; the following gentlemen being named, with power to add to their number, and to consult, viz.:—W. Lees, J. K. Watson, John Milne, Stewart M'Glashan, J. K. Milne, J. Gowans, Bailie Cousin, Dr Ferguson, R. M. Smith; Professor Archer, convener.

VI. The Fellows received, along with the Billet for this evening, the printed Annual Abstract of the Revenue and

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Expenditure of the Society for Session 1870–71, and State of the Funds as at 15th November 1871. (See Appendix T.)

Twelfth Meeting—8th July 1872.—Thomas Ivory, Esq., President, in the Chair.

The following Reports and Communication were read:—

1. Report on Dr Macadam's paper on Water Supply. Dr Ferguson, convener.

2. Report on Mr E. Elmslie Sang's Tool-holder for the Slide-rest. Professor Jenkin, convener.

3. Report on Dr David Gibb's Description of the Ferrie Coking Blast Furnace. Mr Henry Cadell, convener.

4. Report on Mr Robert Thomson's Quadrant Propeller. Mr George Romanes, convener.

5. Report on Mr Thomas Stevenson's Intermittent Light. Mr William Lees, convener.

6 Report on Mr John Scott's Switches for Colliery Railways. Mr William Marshall, convener.

7. Report on Mr Thomas Stevenson's Composite Coloured Plates for Light-houses. Mr W. Lees, convener.

8. Report on Mr Robert Meldrum's Improved Method of Corresponding with Blind Persons. Mr Alexander Fraser, convener.

All of which Reports were adopted.

9. On Colour and Colour Sensation, Part II., by John Aitken, Darroch, Falkirk, was read by Mr Aitken, who exhibited numerous and interesting illustrative Experiments. (See Transactions, p. 389.)

After a few remarks by Mr Sang, Mr Lundy, and Mr Aitken, the communication was remitted to the following Committee:—Professor Swan, Dr Walker, and Dr R. M. Ferguson, convener; and, on account of the lateness of the hour, it was agreed that Mr Aitken's paper be printed, and that the discussion be resumed at a future meeting.

The following Donations were laid on the table, and thanks voted to the respective Donors:—

1. Journal of the Society of Arts, Nos. 1013–1023. Presented by the Society.

2. Engineering, Nos. 329–339. Presented by the Proprietors.

3. English Mechanic, Nos. 369–379. Presented by the Proprietors.

4. Proceedings of the Literary and Philosophical Society of Manchester. Presented by the Society.

5. Transactions of the Institution of Engineers and Shipbuilders in Scotland, April and June. Presented by the Institution.

6. Proceedings of the Literary and Philosophical Society of Liverpool, No. 25. Presented by the Society.

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7. Proceedings of the Royal Society, Nos. 133, 134. Presented by the Society.

8. Journal of the London Institution, Nos. 14, 15. Presented by the Institution.

9. Proceedings of the Institution of Mechanical Engineers, January, 1872. Presented by the Institution.

10. Journal of the Institute of Actuaries, No. 87. Presented by the Institute.

11. Journal of the Scottish Meteorological Society, Nos. 33, 34. Presented by the Society.

12. Report of the British Association (Edinburgh Meeting). Presented by the Association.

13. Proceedings of the Royal Society of Edinburgh, Session 1870–71.

14. Transactions of the Royal Society of Edinburgh, Vol. XXVI. Parts 2 and 3.

Presented by the Society.

15. Edinburgh Astronomical Observations, Vol. XIII. Presented by the Astronomer Royal for Scotland.

16. Thirty-ninth Annual Report of the Royal Cornwall Polytechnic Society. Presented by the Society.

17. Early Typography. By William Skeen, member of the Ceylon Branch of the Royal Asiatic Society. Presented by Mr Skeen.

18. Canal and River Engineering. By David Stevenson, F.R.S.E. Presented by Mr Stevenson.

PRIVATE BUSINESS.

I. On account of the lateness of the hour and the small attendance of Members, the reading of the Minutes was postponed.

II. The Gentlemen recommended by the Council to form the Prize Committee, and whose names had been printed in the Billet, were appointed, viz.:—

Messrs Thomas Bouch,
Henry Cadell,
John Cox,
Thomas Ivory,
Fleeming Jenkin,
William Lees,
J. J. Lundy,
David B. Peebles,
William Marshall,
John Reid,
George Romanes,
John Sturrock,

With the Treasurer, and the Secretary as Convener.

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III. The Gentlemen who previously formed the Publication Committee, whose names also had been announced in the Billet, were, on the recommendation of the Council, re-appointed, viz.:—Dr Ferguson, Sheriff Hallard, Messrs William Lees, John Paterson, J. K. Watson, with the Treasurer, Secretary, and the Editor of Transactions as Convener.

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APPENDIX (R.)

LIST OF PRIZE SUBJECTS FOR SESSION 1872–73.

THE ROYAL SCOTTISH SOCIETY OF ARTS proposes to award prizes of different values, of Thirty Sovereigns, and under, in Gold or Silver Medals, Silver Plate, or Money, for approved Communications, *whether previously published or patented, or not,* submitted to the Society by Fellows or others, relative to Inventions, Discoveries, and Improvements in the *Mechanical* and *Chemical* Arts in general, and in their relation to the Fine Arts, and also to means by which the *Natural Productions* of the Country may be made more available. The Society suggests the following as a few of the many subjects that may be attended to, viz.:—

I. INVENTIONS, DISCOVERIES, or IMPROVEMENTS in the Useful Arts.

1. *Mechanical Arts.*

INVENTIONS or IMPROVEMENTS in applying the Motive Power of Men and Animals,—in Wind and Water Prime Movers,—in Steam and other Heat Engines, including Gas Engines,—in Pumping, Blowing, Rolling, Sawing, Agricultural and other Engines and Machines,—in Cotton and other Textile Manufacturing Mills,—in Ship-building in Wood, Iron, and Steel,—in Lighthouses,—in Marine Propellers,—in Railways, Plant, and Signals,—in Electric Apparatus,—in Electro-Magnetic Motive Power,—in Electric and other Telegraphic Apparatus, Sub-Marine and Aërial,—in Photographic Apparatus,—in Fire-Proof Buildings,—in Water Supply,—in Paving,—Sewerage,—in Economical Appliances for increasing the Sanitary condition of Towns,—in Smoke Consumption and Extinguishing Fires,—in Gas-Works,—

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in Canals and Inland Navigation, including the application of Steam Power to Canal Traffic,—Canal Locks, Inclines, and Lifts,—Application of Hydraulic Power for Lifts for Domestic Use,—for Cranes,—Printing Presses,—Organ-Blowing, and other similar purposes, where small Propelling Power is required,—Labour-saving Machines for working in Wood,—in Tools, Implements, and Apparatus for the various Trades,—in Sewing Machines,—in Bricks, Encaustic Tiles, Cements and Mortars,—in Printing Machines, Cases, and Rollers,—in Stereotyping,—in Cranes,—in the Machinery for Collieries,—in preserving Timber and Metals in Marine Works,—in Optical Apparatus,—in Manufacture of Paper,—Experiments on the Effect of Low Temperatures on Metals.

2. *Chemical Arts.*

INVENTION or IMPROVEMENTS in new and useful applications of Gutta Percha and Vulcanised India Rubber, or similar Gums,—in the Economical Extraction of Chemical Principles or Useful Substances, as Paraffine, &c., from Coal,—Porcelain Clay from Granite or Felspar,—and Metals generally from their Ores and Oxides,—in Dyes,—in Paints,—in Paper,—in Glass, especially for Lenses,—in methods of rendering the Electric Light available in practice.

3. *Relative to the Fine Arts.*

INVENTIONS or IMPROVEMENTS in Photographic processes, in "Carbon" Printing, and in Methods of Printing Photographs from their Impressions on Steel or Copper Plates, or Lithographic Stones,—in Electrotype processes,—in Die-Sinking,—in methods of illustrating Books, to be printed with the letterpress,—in Paper-Hangings,—in Articles of Porcelain, Common Clay, or Metal,—in Glass-Staining,—in Engraving on Stone,—in Chromo-Lithography,—in "Nature" Printing.

4. *Natural Productions.*

DISCOVERY of Plumbago Mines,—Whetstones,—of Woods suitable for Engraving.

II. EXPERIMENTS applicable to the Useful Arts.

III. COMMUNICATIONS of Processes in the Useful Arts practised in this or other Countries, but not generally known.

IV. PRACTICAL DETAILS of Public or other Undertakings of National importance, already executed, but not previously published;—or valuable suggestions for originating such undertakings.

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The KEITH PRIZE, value Thirty Sovereigns.

For some important "Invention, Improvement, or Discovery in the Useful Arts, which shall be primarily submitted to the Society" during the Session.

The HEPBURN BIENNIAL PRIZE, value about £12.

(*If not awarded during Session* 1870–71.)

For such Inventions or Communications submitted to the Society as shall be approved of by the Society, or by their Prize Committee."

The MAKDOUGALL-BRISBANE BIENNIAL PRIZE, value £10

(*If not awarded during Session* 1870–71.)

"To the Authors or Inventors of Communications of Merit, which shall be approved of by the Society, or its Committee, and judged by them deserving of such distinction."

The REID and AULD PRIZES.

For the First, Second, and Third best Models of "Anything New in the Art of Clock or Watch Making,—by Journeymen or Master Watch and Clock Makers,"—if these should be considered worthy of Prizes, the Year's Interest of the Reid and Auld Bequest, being about SEVEN GUINEAS, divided among them in such proportions as the Prize Committee shall fix, according to merit. To such as deserve it, the Society may add to the amount of the Prize out of its general funds.

GENERAL OBSERVATIONS

AND DIRECTIONS FOR PREPARING AND LODGING COMMUNICATIONS.

The descriptions of the various inventions, &c., must be *full* and *distinct;*—be legibly written on *Foolscap* paper, leaving margins at least one inch and a half broad, on *both sides of each page,* so as to allow of their being bound up in volumes; and, when necessary, be accompanied by *Specimens, Drawings, or Models.* All Drawings to be on *Imperial* Drawing-Paper, unless a larger sheet be requisite. The Drawings to be in *bold* lines, not less than a quarter of an inch broad, or *strongly coloured,* so as to be easily seen at about the distance of thirty feet when hung up in the Hall, and the Letters or Figures of Reference to be at least 1½ inch long. When necessary, smaller and more minutely detailed Drawings should

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accompany the larger ones, for the use of the Committees, having the same letters of reference. Short abstracts must accompany the papers.

The Society shall be at liberty to publish in their Transactions copies or abstracts of all papers submitted to them. All Models, Drawings, &c., for which Prizes are given, shall be held to be the property of the Society; but the Value of the Model, if retained, will be separately allowed for.

Communications, Models, &c., are to be addressed to the SECRETARY, 2 George Street, Edinburgh, Postage or Carriage paid; and should be lodged on *or before* 2*d January* 1873, in order to insure their being read and reported on during the Session (the ordinary Meetings of which commence in November 1872, and end in April 1873). Communications lodged after the 1st March may not be read or reported on till the following Session.

By order of the Society.

EDWARD SANG, *Secretary.*

EDINBURGH, *April* 1871.

*** *Copies for distribution may be had from the Secretary.*

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APPENDIX (S.)

REPORT

OF

THE COMMITTEE

APPOINTED BY

THE ROYAL SCOTTISH SOCIETY OF ARTS

TO AWARD PRIZES FOR COMMUNICATIONS READ AND EXHIBITED DURING SESSION 1871-72

Your COMMITTEE having met and carefully considered the Communications laid before the Society, or reported on during the Session 1871–72, beg to report—

That the Special Thanks of the Society are due to ROBERT WILLIAM THOMPSON Esq. C.E., F.R.S.E., late President,—for his Address, read for him by Professor Archer, on the opening of the Session.

That your Committee have awarded the following Prizes, viz.:—

1. To STEVENSON MACADAM, Ph.D., F.R.S.E., Lecturer on Chemistry—for his paper and researches "On the Relative Photogenic Values of Vegetable, Animal, and Mineral Oils, and of Coal Gas;" read, and profusely illustrated, on November 27th 1871 (No. 4263).

The Brisbane Prize, value Ten Sovereigns.

2. To Dr. STEVENSON MACADAM for "Experiments and Investigations detailed in his Paper on Water-Supply" read on 8th January 1872 (No. 4266).

The Society's Silver Medal, Value Five Sovereigns.

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3. To EDWARD ELMSLIE SANG, C.E.—for his "Description of a new Tool-Holder, for the Slide Rest"—read on 22d January 1872 (No. 4267).

A Keith Prize, value Five Sovereigns.

4. To JOHN SCOTT, manager at Garriongill Coal Works,—for his "Apparatus for working Railway Switches," described by David Landale Esq. C.E. and illustrated by models, on 8th April 1872 (No. 4278).

A Keith Prize, value Five Sovereigns.

5. To ROBERT MELDRUM, teacher of the blind, Alloa,—for his Description of an "Improved Method of Corresponding with Blind Persons,"—read, and apparatus exhibited, on 22d April 1872 (No. 4279).

A Keith Prize, value Five Sovereigns.

6. To THOMAS STEVENSON, C.E., F.R.S.E.,—for his Papers (No. 4277) on an "Intermittent Light for Light-Houses," and (No. 4281) on "Composite Coloured-glass Plates,"—read, and illustrated, on 8th April 1872.

The Society's Silver Medal, value Three Sovereigns.

7. To ALEXANDER LESLIE, C.E.,—for his Paper on "the Water Supply of Berwick,—read on 22d January 1872 (No. 4268).

The Society's Honorary Silver Medal.

8. To Professor THOMAS C. ARCHER, F.R.S.E., Director of the Museum of Science and Art,—for his paper "On the Ingenuity displayed in the manufacture of German Toys,"—read, and profusely illustrated, on 26th February 1872 (No. 4274).

The Society's Honorary Silver Medal.

9. To ROBERT M. FERGUSON, Ph.D., F.R.S.E.,—for his "Description of a simple way of showing the Motion of Waves on the surface of a Liquid," read, and illustrated by means of the lime light, on 11th March 1872 (No. 4276).

The Society's Honorary Silver Medal.

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10. To Dr DAVID GIBB, Medical officer at the Monkland Iron Works,—for his "Description of the Ferrie Coking Blast Furnace, as in use at the Monkland Iron and Steel Works,"—read, and illustrated by numerous specimens and drawings, on 25th March 1872 (No. 4273).

The Society's Honorary Silver Medal.

And that while *Thanks* are justly due to all those gentlemen who have sent Communications, the *Special Thanks* of the Society are due to the following gentlemen:—

1. To JOHN PATERSON, C.E.,—for his "Notes on Sewerage,"—read on 12th February 1872 (No. 4270).

2. To JOHN G. WINTON, C.E.,—for his paper "on Sanitary Liftings,"—read on 12th February 1872 (No. 4271).

Note.—The Paper on Colour and Colour Sensation, read by Mr John Aitken, on 12th February and 8th July 1872, was not taken into consideration by the Committee, as it had been remitted to the following session.

All which is humbly reported, in name and by order of the Committee, by

EDWARD SANG,
Sec., Convener ex officio.

SOCIETY'S HALL, 117 GEORGE STREET.
15*th October* 1872.

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APPENDIX (T.)

ABSTRACT OF THE ACCOUNTS OF THE SOCIETY FOR 1870–71.

I. REVENUE AND EXPENDITURE.

I. GENERAL FUNDS.

Revenue.				Expenditure.			
Arrears of Annual Contributions received	£14	14	0	1. ORDINARY—			
Annual Contributions for Session 1870–71 received	247	16	0	Prizes awarded	£20	0	0
Compositions in lieu of Annual Contributions received, £27, 5s. 0d., whereof 5 per cent. applicable to Revenue, as recommended by Committee on Accounts	1	7	3	Printing and Advertising	43	1	4
Balance transferred from Building Fund (*page 2nd*),	29	13	3¾	Expenses of the Society's Printed Transactions	62	15	6
				Fees to Committees for Reports	10	0	0
				Repairs, Furnishings, &c., for the Hall	10	18	6
				Salaries & Expenses of Collection	107	11	0
				Miscellaneous Payments	6	8	11
					£260	15	3
				Balance, being Excess of Revenue over Expenditure,	32	15	3¾
	£293	10	6¾		£293	10	6¾

II. KEITH BEQUEST.

REVENUE.

Dividends from Edinburgh Gas-Light Company's Stock	£15	0	0
Dividends from British Linen Company Bank Stock	13	0	0
Dividends from Royal Bank Stock	20	0	0
Interest on Bank Account	0	15	2
Amount	£48	15	2

EXPENDITURE.

Prizes Awarded	20	0	0
Excess of Revenue	£28	15	2

III. REID AND AULD BEQUEST.

REVENUE.

Dividends from National Bank Stock	£13	0	0
Interest on Sums in Bank	0	4	9
Amount	£13	4	9

IV. BRISBANE BIENNIAL PRIZE FUND.

REVENUE.

Dividends from Government Stock	£5	2	11
Interest on Bank Account	0	2	8
Amount	£5	5	7

V. HEPBURN PRIZE FUND.

REVENUE.

Dividends from Caledonian Railway Company Stock	£7	5	11
Interest on Bank Account	0	2	4
Amount	£7	8	3

EXPENDITURE.

Prize Awarded	7	0	0
Excess of Revenue	£0	8	3

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I. REVENUE AND EXPENDITURE—continued.

VI. BUILDING FUND.

REVENUE.

Rents drawn from Letting of Hall		£145	13 6
Interest on Bank Account		0	19 4
		£146	12 10

EXPENDITURE.

Payments on account of Hall, viz., Taxes, Feu-duty, Insurance, Coals, Gas, Cleaning, &c., and Hall Keeper's Salary	£90	4	6½		
Interest on Debt,	26	15	0		
				116	19 6½
Excess of Revenue transferred to General Fund, (p. 1*st*),				£29	13 3½

II. FUNDS OF THE SOCIETY.

As at 15th November 1871, *per Report of Committee on Books and Accounts.*

I. GENERAL FUND.

1. Price of Hall in George Street and Furnishings, and of the additional Premises purchased at Whitsunday 1863				£2,712	0 3
2. Arrears of Annual Contributions				29	8
				£2,741	8 3
Less—1. Balance due to Commercial Bank	£590	15	10		
2. Balance due to Treasurer	36	13	9½		
3. Balance of Subscriptions for Expenses of Conference on Technical Education unexpended	9	5	2		
				636	14 9½
AMOUNT				£2,104	13 5½

II. KEITH BEQUEST.

1. Six Shares of the Edinburgh Gas-Light Company, at £53	£318	0	0		
2. £100 Stock of the British Linen Company's Bank	272	0	0		
3. £250 Stock of the Royal Bank, at £179	457	10	0		
4. Balance in Commercial Bank	78	11	10		
AMOUNT				1,126	1 10

III. REID AND AULD BEQUEST.

1. £100 National Bank Stock	£287	0	0		
2. Balance in Bank	186	1	0		
AMOUNT				473	1 0

IV. BRISBANE PRIZE FUND.

1. £175, 3 per cent. Consols, at 93⅛	£162	19	4½		
2. Balance in Bank	16	6	3		
AMOUNT				179	5 7½

V. HEPBURN PRIZE FUND.

1. £100 Stock of the Scottish Central Railway Company	£150	15	0		
2. One £10 Share, No. 2, 4½ per cent. Preference Stock of do.	10	0	0		
3. Balance in Bank	10	17	7		
AMOUNT				171	12 7

VI.

Balance of Subscriptions for Expenses of Conference on Technical Education unexpended		9	5 2
Total value of Property and Funds under charge of the Society as at 15th November 1871		£4,063	19 8½

JOHN SCOTT MONCRIEFF, *Treasurer.*

EDINBURGH, 13*th April* 1872.

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APPENDIX (U.)

LIST

OF THE

OFFICE-BEARERS AND FELLOWS

OF THE

ROYAL SCOTTISH SOCIETY OF ARTS,

AS AT 1st NOVEMBER 1872.

THE QUEEN, PATRONESS.

OFFICE-BEARERS FOR SESSION 1871-72.

President, ... THOMAS IVORY, Advocate, 23 Walker Street.

Vice-Presidents, ... HENRY CADELL, M.E., The Grange, Bo'ness.
JOHN REID, Rose Mount, Ferry Road.

Secretary, ... EDWARD SANG, F.R.S.E., 2 George Street.

Treasurer, ... JOHN SCOTT MONCRIEFF, C.A., Chambers, 26 Frederick Street.

Editor of Transactions, STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., &c., Surgeon's Hall, Nicolson Street.

Curator of Museum, ... ALEXANDER JAMIESON, Nicolson Square.

Medalist, ... ALEXANDER KIRKWOOD, 9 St James' Square.

Officer and Collector, ... JOHN BELL, 117 George Street.

Councillors.

*GEORGE HARRISON, Merchant, 12 Blackford Road.

*Professor FLEEMING JENKIN, F.R.S.S. L. & E., 5 Fettes Row.

*D. C. MUDIE, Panmure Foundry.

*JAMES TOD, 3 St James' Square.

JOHN STURROCK, 3 Queen's Crescent.

JOHN W. TAWSE, W.S., 49 Queen St.

ALEXANDER REID, 31 Castle Street.

DAVID BRUCE PEEBLES, 18 Viewforth Terrace.

JOHN J. LUNDY, F.C.S, F.G.S., Assembly Street, Leith.

JOHN COX, Gorgie House, Murrayfield.

ALEXANDER LESLIE, C.E., 39 Northumberland Street.

DAVID MARSHALL, 6 Bernard Street, Leith.

The four Ordinary Councillors marked * retire by rotation.

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LIST OF THE ORDINARY FELLOWS,

AS AT 1ST NOVEMBER 1872.

*Those marked * are Life Fellows.*

NOTE.—Fellows may become "Life Fellows" at any time on paying £10, 10s., from which they are allowed a deduction of half the amount they may have paid previously in Annual Contributions.

1822 *ABERCORN, His Grace James, Duke of, K.G., &c., Hampden House, London
1850 *Adie, A.J., F.R.S.E., C.E., 5 St Andrew Square
1860 Adie, Richard, optician, 50 Princes St.
1863 Aitchieson, Thos. Stodart, 85 South Back of Canongate
1860 Aitchison, William John, 11 Buckingham Terrace
1865 Aitken, Henry, manager, Darroch Coal and Iron Works, Falkirk
1871 Aitken, John, Darroch, Falkirk
1860 Alder, Henry, gas-meter maker, 32 Grange Road
1851 *Alexander, William, M.E., 23 India Street, Glasgow
1841 *Anderson, Charles W., merchant, 2 Mansion House Road
1871 Anderson, Richard, manager, Uddingstone Oil Works, Glasgow
1850 *Anderson, Thos., M.D., F.R.S.E., Professor of Chemistry, University, Glasgow
1863 Andrews, James, C.E., 84 George St.
1861 Archer, Thos. C., F.R.S.E., Director of the Museum of Science and Art
1868 Archibald, John, M.D., Biggar
1826 *Aytoun, Robert, W.S., 3 Fettes Row

1867 *Baillie, John M., C.A., 15 Northumberland Street
1872 Barr, John M'Queen, accountant, 33 Renfield Street, Glasgow
1871 Beatson, William, burgh surveyor, Town Hall, Leith
1865 Beattie, Adam, builder, 3 Chalmers St.
1871 Beattie, Robert P., plumber, 19 South Castle Street
1861 Beith, Donald, W.S., 43 Castle Street
1850 *Bell, Alexr. Melville, Melville House, Paris, near Toronto
1859 *Bell, Andrew Beatson, advocate, Court-House, Cupar-Fife
1857 Bell, B., surgeon, 8 Shandwick Place
1858 Bell, James, railway-engineer, 28 Brighton Place, Portobello
1867 Bell, Robert, coal-merchant, Broxburn
1861 Bell, William, stockbroker, 8 North St David Street
1867 Bennet, James Henry, engineer, 4 Summerfield, Leith
1847 *Bernard, Thomas, brewer, 5 Carlton Terrace
1859 Black, Adam, publisher, 38 Drummond Place
1850 *Black, Rev. Arch. Pollok, LL.D., The Manse, Bow Road, London
1868 Blair, Rev. Rob. Hugh, M.A., F.R.A.S., rector of St Martin's, Worcester.
1863 *Blanshard, George, wholesale druggist, 7 Carlton Terrace
1872 Blyth, Benjamin Hall, junior, C.E., 135 George Street
1849 *Bouch, Thomas, C.E., 78 George Street
1853 *Bow, Robert Henry, C.E., F.R.S.E., 7 South Gray Street
1863 Bowie, Andrew F., 4 Pilrig Street
1870 Boyd, George Pratt, gas engineer, Alloa
1868 Boyd, James L., S.S.C., 1 Regent Terrace
1848 *Brebner, Alan, engineer, 84 George St
1861 Brown, D. R., manufacturing chemist 1 St John Street
1864 Brown, Geo. Bruce, architect, 26 Elder Street
1868 *Bruce, C., banker, 2 Glenfinlas Street
1850 *Bruce, George Cadell, C.E., 21 Castle Street
1833 *Bryce, David, architect, 131 George St.
1851 *Bryden, J., bell-hanger, 55 George St.
1857 Bryson, J. M., optician, 60 Princes Street
1860 Bryson, Robt., watchmaker, 66 Princes Street
1822 *BUCCLEUCH and QUEENSBERRY, His Grace Walter, Duke of, K.G., A.M., F.R.SS. L. & E., Dalkeith Palace

1851 *Cadell, Henry, M.E, Grange, Bo'ness, *Vice-President*
1846 *Callender, John A., merchant, India Buildings
1859 *Cameron, P., contractor, 25 George Square
1834 *Campbell, Alex., brewer, 6 Charlotte Square
1862 Carlisle, James, engineer, 5 Hope Park Crescent
1865 *Carmichael, Peter, Den's Works, Dundee
1858 Carphin, James R., C.A., 26 Northumberland Street

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1840 *Carstairs, Drysdale, merchant, Liverpool
1864 Carter, Frederick Hayne, C.A., 8 Eton Terrace
1867 *Cay, Wm. Dyce, C.E., 7 Blackford Road
1864 Chalmers, T., Longcroft, Linlithgow
1860 Charnock, Richard Stephen, 8 Gray's Inn Square, London
1857 *Chaumont, F. De., M.D., 1st Battalion Rifle Brigade, Woolston, Southampton
1861 Chisholm, David, actuary, 9 Rill Bank Terrace
1856 *Chisholm, John Knox, dentist, 15 Duke Street
1860 Christie, John, Brae Lodge, Murrayfield
1872 Clapperton, John, merchant, 371 High Street
1866 Clapperton, W. R., merchant, 59 Princes Street
1862 Copland, Harry Y. D., 27 Stafford St.
1847 *Cousin, David, city-architect, City Chambers
1869 Cousin, George, architect, 5 Bruntsfield Terrace
1836 *Cowan, Charles, Wester Lea, Murrayfield
1864 Cox, John, glue manufacturer, Gorgie House, Murrayfield
1872 Coyne, Roderick A. F. A., C.E., 11 Royal Exchange
1866 *Craig, James, distiller, 33 Manor Pl.
1865 *Craig, Robert, paper-maker, Craigesk, Dalkeith
1832 *Craig, Sir William Gibson, of Riccarton, Bart, F.R.S.E., Hermiston
1860 Cuningham, Alex., secretary to the Commissioners for Northern Lights, 84 George Street
1851 *Cunningham, George, C.E., 2 Ainslie Place
1857 *Cunningham, James, W.S., F.R.S.E., 50 Queen Street
1863 Currie, Heriot, engineer, 4 Auburn Place North Leith
1867 Cusiter, G. F., gas-engineer, Dalkeith

1868 Davidson, James, M.E., Newbattle
1850 *Davison, Samuel D., Boswell House, Wardie
1865 Day, St John Vincent, C.E., 166 Buchanan Street, Glasgow
1867 Deans, Peter Dods, Mount Charles, Bath Street, Portobello
1865 Deas, James, C.E., Glasgow
1844 *Dickson, J. Jobson, C.A., 13 Clarendon Crescent
1850 *Dickson, John, junior, gunmaker, 63 Princes Street
1866 Dods, G., assessor of railways, 5 Gayfield Square
1860 *Douglas, F. Brown, 21 Moray Place
1859 *Dryborough, Rich., cooper, 4 Hermitage Place, Leith
1866 Dunn, John H., 13 Glengyle Terrace
1844 *Dunn, Thos., optician, 7 Buccleuch Place

1853 Elliot, Professor James, Goldielands, Hawick
1839 *Ellis, T., upholsterer, 21 George IV. Bridge
1864 Ellis, W. M., merchant, 8 Wellington Street, Portobello
1857 Esson, Geo. A., accountant in Bankruptcy, 10 Great King Street

1850 *Falshaw, James, C. E., 26 Castle Street
1864 *Ferguson, John, engraver, North St Andrew Street
1857 Ferguson, R. M., Ph.D., F.R.S.E., 12 Moray Place
1850 *Ferguson, William Black, C.E., 129 Union Street, Aberdeen
1871 Ferrier, Robert, inspector of gas meters, Royal Exchange
1869 Fidler, Thomas Claxton, C.E., Olney, Bucks
1864 Field, Thomas, slate-merchant, 27 Frederick Street
1860 Firth, William, secy., N. B. Rubber Co., Rose Villa, Viewforth
1840 *Fleming, Alex., W.S., 20 Lynedoch Place
1861 Fleming, A. B., chemical manufacturer, 12 Eton Terrace
1868 Forman, John, 51 Great King Street
1869 Forrest, Thomas, junior, ironmonger, 29 South Clerk Street
1840 *Forrester, John, W.S., 8 Drummond Place
1871 Foulis, William, gas engineer, 42 Virginia Street, Glasgow
1850 *Fraser, Alexander, printer, Old Fish-market
1847 *Fullarton, John A., publisher, 12 Claremont Street

1869 Galt, Robert, jun., coal-master
1856 *Geddes, A. C., C.E.
1856 *Geddes, G. H., M.E., 9 Lynedoch Place
1872 Gibb, David, M.D., Rosehill House, Airdrie
1842 *Gillespie, John, W.S., 53 Northumberland Street
1854 *Girdwood, Robert, merchant, 77 Great King Street
1850 *Glennie, Geo., C.E., 43 Upper Thames Street, London
1871 Glover, Thomas Craigie, C.E., 29 Hope Terrace, Grange

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1859 Gordon, Alexander, colliery manager, Thorniebank, Dalkeith
1861 Gowans, Alex., 3 Viewforth Road
1850 *Gowans, James, builder, 31 Castle Ter.
1865 Gray, Alex., ironmonger, 85 George Street
1832 *Gray, James, ironmonger, 39 Gt. King Street
1860 Gray, Rev. W. H., M.A., D.D., minister of Lady Yester's, 15 Coates Gardens
1850 Gregory, Thos. Currie, C.E., Glasgow
1858 Greig, David, engineer, Greenhill Park
1835 *Groat, A. G., of Newhall, 12 Hart Street

1872 Hall, Thomas, painter, 1 Queen Street
1855 Hallard, Fredk., F.R.S.E., Sheriff-substitute of Edinburgh, 61 York Place
1833 *Hamilton, Alexander, W.S., LL.B., F.R.S.E., 35 Queen Street
1860 Hardie, Walter, printer, 77 Rose Street
1866 Harrison, G., merchant, 12 Blackford Road
1870 Hartnell, Wilson, engineer, 87 Bernard Street, Ipswich
1840 *Harvey, Sir George, P.R.S.A., F.R.S.E., 21 Regent Terrace
1853 *Hay, Geo. W., of Whiterigs, F.R.S.E., Devon Lodge, Starcross, Devon
1835 *Hay, James, F.R.S.E., merchant, Leith
1867 Hay, William, architect, 17 Hill Street
1856 *Henry, Alex., gunmaker, 12 South St. Andrew Street
1871 Herbert, R.C.S., veterinary surgeon, East Currie Farm, Currie
1839 *Hill, Laurence, jun., C.E., Inch Works, Port-Glasgow
1871 Hislop, George Robertson, F.C.S., gas engineer, Blackstone Road, Paisley
1863 Hogue, D. W., M.D., dentist, 65 Queen Street
1864 *Hood, Archibald, M.E., Whitehill Colliery, Lasswade
1870 Horne, Robert Reston, Kenmuirhill Colliery, Toll Cross, Glasgow
1868 Horsburgh, John, photographer, 131 Princes Street
1834 *Horsburgh, Robt., Southbank House, Penicuik
1838 *Hunter, Richard, H.E.I.C.S., 10 Ainslie Place

1857 Imlach, Francis B., F.R.C.S.E., 48 Queen Street
1859 Ivory, Thomas, advocate, 23 Walker Street, *President*

1854 Jackson, Ed. James, B.A. Oxon., 6 Coates Crescent
1850 *Jardine, Wm. Alex., C.E., 19 Queen Street
1848 *Jefferiss, Robert R., M.D., Dalkeith
1868 Jenkin, Fleeming, F.R.SS. L. & E., Professor of Civil Engineering, 5 Fettes Row
1858 Johnston, Adam, solicitor, 1 Register Place
1867 Johnstone, James, of Larchhill, 9 Royal Terrace
1850 *Johnstone, William, C.E., 14 Bridge Street, Glasgow
1850 *Jopp, Charles, C.E., 3 Royal Terrace

1857 *Kay, John Zuill, Phœnix Iron Works, Glasgow
1870 Keane, John, C.E., office of Public Works, Calcutta
1839 *Kennedy, Wm., W.S., 59 Northumberland Street
1867 Kennedy, W. Wemyss, machinist, 101 Princes Street
1865 Kerr, John F., gas-engineer, Copiapo, Chili
1836 *Kirkwood, Alex., *Medalist*, 9 St James' Square
1857 Kirkwood, Wm. B., accountant, 6 St Andrew Square

1861 L'Amy, Sylvester
1857 Landale, Andrew, iron-master, Lochgelly
1852 *Landale, David, M.E., 6 Forth Street
1868 Landale, James, M.E., 6 Forth Street
1836 *Lawson, Charles, of Borthwick Hall, 35 George Square
1858 Lawson, Charles, jun., seedsman, 34 George Square
1859 Lawson, George Stodart, 35 George Square
1836 *Lees, George, LL.D., St Andrews
1850 *Lees, Henry, accountant, 6 York Place
1856 Lees, William, A.M., Linkvale, Viewforth
1866 *Leslie, Alexander, C.E., 39 Northumberland Street
1850 *Leslie, James, C.E., 72 George Street
1850 *Lessels, John, architect, 21 Heriot Row
1863 Lockhart, James, engineer, Ivy Bank, Greenock
1852 *Lorimer, James, C.E., 99 George Street
1862 Lundy, J. J., F.C.S., F.G.S., Assembly Street, Leith

1856* Macadam, Stevenson, Ph.D., F.R.S.E., *Editor of Trans.*, Surgeons' Hall
1839 *Macbrair, David J., S.S.C., 12 Great King Street
1870 M'Connell, Frederick, of Robgill, Kirtle Lodge, Trinity

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1871 MacCrae, B.M., gas engineer, Peep-o-day House, Dundee
1850 *Macdonald, D., cotton-spinner, Aberdeen
1872 Macdonell, Eneas R., of Morar, 7 Coates Crescent
1871 Macfarlane, Arthur Albert, veterinary surgeon, 25 Blackhall St., Greenock
1868 Macfarlane, Walter, 231 St Vincent Street, Glasgow
1861 M'Glashan, Stewart, sculptor, Canonmills Bridge
1850 *Mackay, John, pharmaceutical chemist, 121 George Street
1871 M'Kelvie, James, coalmaster, Haymarket
1861 Mackenzie, Charles, bookseller, 40 Greenhill Gardens
1870 Mackenzie, James, 5 Grange Place
1871 Mackenzie, John, M.E., 11 Cornwall Street
1870 Mackenzie, William, gas manager, Dunfermline
1839 *Maclagan, Douglas, M.D., F.R.S.E., Prof. of Medical Jurisprudence, 28 Heriot Row
1870 Maclagan, John Thomson, manufacturing chemist, 7 James Place, Leith
1863 *Maclagan, Peter, of Pumpherston, M.P., Mid-Calder
1867 *Maclagan, R. Craig, M.D., 5 Coates Crescent
1866 M'Laren, Duncan, M.P., Newington House
1858 M'Lean, Hector Frederick, W.S., 3 Hill Street
1868 M'Leod, William Bowman, dentist, 43 George Square
1861 M'Nab, John, Inglis Green, Slateford
1861 Macnair, John, 33 Moray Place
1867 Macnaughton, Alexander, S.S.C., 18 Young Street
1872 M'Neill, John, plumber, 6 Mill Street, Perth
1863 Macnie, John, gas-engineer, Lecky Road, Londonderry
1872 Macrae, John, C. E., 107 Princes Street
1850 *Marjoribanks, William, merchant, Warriston House
1867 Marshall, David, engineer, 6 Bernard Street, Leith
1858 Marshall, Thomas R., goldsmith, East Castle Road, Merchiston
1860 Marshall, William, engineer, Madeira Street, North Leith
1870 Marshall, William, coal-merchant; 14 South Charlotte Street
1869 Mason, Samuel Lack, general manager, North British Railway, Pentland Villa, West Coates
1860 Matheson, Robert, architect, 25 Abercromby Place
1850 *Mein, Archibald, dentist, 94 George Street
1861 *Meldrum, Edward, of Dechmont, F.R.S.E., Broxburn
1860 Melville, F. Suther, assistant-clerk of Session, 4 Abbotsford Park
1863 Menzies, Duncan, architect, 13 Young Street
1865 Menzies, Wm. John, W.S., Canaan Cottage
1857 *Millar, John, merchant, 13 York Place
1870 Miller, James N., 77 Queen Street, Glasgow
1829 *Miller, Jn., of Leithen, C.E., F.R.S.E. M.P., 2 Melville Crescent
1868 Miller, Richard R., Upper Hermitage
1861 Millidge, J. J., goldsmith, 28 Princes Street
1859 *Miln, James, of Murie
1865 Milne, James, engineer, 16 Windsor Terrace, Glasgow
1848 *Milne, John Kolbe, dressing-case maker, 126 Princes Street
1859 *Milne, John, Grove, Trinity
1850 *Moffatt, William Lambre, architect, 23 Minto Street
1838 *Moncrieff, John Scott, C.A., *Treasurer*, 26 Frederick Street
1865 Moore, Wm., M.E., 49 West George Street, Glasgow
1863 More, James L., 14 Henderson Row
1854 Morrison, Adam, S.S.C., 45 York Place
1872 *Morrison, James, 102 Renfield Street, Glasgow
1838 *Morton, Hugh, engineer, Victoria Dock, Leith
1855 *Mossman, Adam, jeweller, 30 Princes Street
1858 Mudie, D. C., Panmure Foundry, North Back of Canongate
1857 Muir, John, brewer, 5 Pilrig Street
1857 Muir, R. G., brewer, 9 Bellevue Ter.
1869 Muir, William Hamilton, of Shawhill, 18 Picardy Place
1866 Muir, W. J. Cockburn, C.E., 9 Victoria Chambers, Westminster, London
1861 Muirhead, And., painter, 32 Frederick Street
1868 Murray, John, 48 Castle Street
1872 Murray, William, wine-merchant, 2 St Andrew Square

1838 *Nachot, H. W., Ph.D., teacher of German, 73 Queen Street
1868 Nairn, Andrew, 21 Albany Street, Leith
1860 Nelson, Thomas, publisher, Hope Park
1858 Nicol, John, chemist, 4 Dundas St.

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1850 *Ogilvie, A., merchant, Old Liston, Ratho
1866 Oliver, John S., merchant, 8 Greenhill Park
1860 Ower, C., engineer, Craigie Terrace, Dundee

1865 Park, Ebenezer, engineer, 18 Greenside Lane
1863 Park, James Dove, engineer, 18 Greenside Lane
1866 Parkes, S. H., 5 St Mary's Road, Birmingham
1844 *Paterson, John, C.E., 27 Hope Terrace
1846 *Paterson, W., Scot. Cent. Rail., Perth
1859 Paterson, Wm., banker, 4 Regent Ter.
1840 *Pearson, Charles, C.A., 128 George Street
1861 Peebles, D. B., engineer, 18 Viewforth Terrace
1865 *Peters, A. M., plumber, 13 Dundas St.
1862 Pilkington, F. T., architect, 2 Hill St.
1861 Platt, Leon J., dentist, Stirling
1868 Potts, R. Collins, 15 Henderson Place, Ferry Road
1864 Proudfoot, David C., City Road Trust, 13 Glengyle Terrace

1862 Rainie, Robert, C.A., 6 Clifton Ter.
1850 *Ramsay, Alex., Greenhill Park
1835 *Ranken, Francis, glass-merchant, 16 Picardy Place
1842 *Rankine, W. J. Macquorn, F.R.SS. L. and E., Prof. of Civil Engineering, 59 St Vincent Street, Glasgow
1857 *Reid, A., optician, 31 Castle Street
1860 Reid, John, engineer, Edin. and Leith Gas Co., Rosemount, Ferry Road, *Vice-President*
1848 *Reid, R. L., painter, 2 Blenheim Place
1843 *Rhind, David, F.R.S.E., architect, 54 Great King Street
1850 *Richardson, R., merchant, 16 Bruntsfield Place
1853 Ritchie, A., watchmaker, 29 Leith St.
1867 Ritchie, David, smith, 14 Lauriston Gardens
1865 Ritchie, Frederick James, clockmaker, 25 Leith Street
1862 Ritchie, James, wholesale stationer, 13 Blacket Place
1866 Ritchie, Jas., M.R.C.S., M.B., C.M., 14 East Claremont Street
1870 Roberts, George, builder, 1 Grosvenor Street
1843 *Roberts, W. A., M.D., dentist and surgeon, 30 Queen Street
1859 Robertson, G., M. Inst. C.E., F.R.S.E., 47 Albany Street
1855 *Robertson, J., druggist, 35 George St.
1857 Rollo, Right Hon. Lord, Duncrub House, Bridge of Earn
1868 Romanes, George, C.E., 5 St Andrew Square
1853 *Rose, J. T., shipbuilder, 1 Duncan Street, Drummond Place
1869 Rowatt, Thomas, lamp-manufacturer, Palmerston Road
1838 *Roxburghe, His Grace James H. R., Duke of, K.T., Floors, Kelso
1866 Russel, John, merchant, 4 Baxter's Place
1835 *Russell, J. Scott, C.E., F.R.SS. L. & E., Sydenham, London
1872 Russell, Richard F., Uddingston Oil Works, Glasgow

1864 Samuel, Peter, merchant, 15 Hanover Street
1843 *Sanderson, J. H., lapidary, 92 Princes Street
1867 Sanderson, William, rectifier, Quality Street, Leith
1869 *Sang, David, 9 Brandon Street
1828 *Sang, Edward, F.R.S.E., 2 George Street, *Secretary*
1860 Sang, Edward Elmslie, C.E., 2 George Street
1843 *Schenck, Frederick, lithographer, 11 Lothian Street
1870 Scott, Robert, Addiewell Chemical Works, West Calder
1850 *Scrymgeour, Henry, upholsterer, 73 George Street
1843 *Shanks, Thomas, engineer, Johnston, Renfrewshire
1869 Shaw, P., contractor, 6 Cambridge Street
1862 *Shedden, Thomas, M.A., Arrochar
1870 Sheriff, Thomas, L.R.C. Ph. and S. Ed., The Villa, Ratho
1866 Sim, Francis Ranken, glass-merchant, 96 Princes Street
1863 Sim, William, Edinburgh Colour Works, Jane Street, Leith Walk
1865 Simpson, George, Bonhar Colliery, Whitburn
1864 Simpson, James, architect, Daisy Bank, Ferry Road
1856 Slight, G. H., engineer, Dock Foundry, Orchard Street, Blackwall, London
1862 Sligo, A. V. S., of Inzievar, 5 Drummond Place
1857 Smith, Adam G., C.A., 5 Lennox Street
1850 *Smith, A., C.E., 4 Union Place, Aberdeen
1839 *Smith, D., F.R.S.E., manager, North British and Mercantile Insurance Co., 64 Princes Street
1865 Smith, David, contractor, 61 Brougham Street, Belfast
1865 Smith, John D., carver and gilder, 21 Frederick Street

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1872 Smith, John Guthrie, advocate, Sheriff of Aberdeen, 10 Abercromby Place
1856 Smith, Robt. M., F.R.S.E., merchant, 4 Bellevue Crescent
1859 Smith, William, lithographer, 43 Northumberland Street
1855 Smyth, Chas. Piazzi, F.R.SS. L. & E., Astronomer-Royal for Scotland, 15 Royal Terrace
1865 Soutter, James, merchant, 102 Princes Street
1859 Spence, W., Sec., B. L. Co. Bank, 36 St Andrew Square
1540 *Sprot, T., W.S., 10 Drummond Place
1850 *Stark, James, M.D., F.R.C.P., F.R.S.E., 21 Rutland Street
1870 Steel, James, 103 St Vincent Street, Glasgow
1835 *Steele, Pat. S., merchant, Eastbourne House, Portobello
1867 Steuart, Charles, jun., W.S., 8 Doune Terrace
1847 *Steuart, James, W.S., 8 Doune Ter.
1838 *Stevenson, David, C.E., F.R.S.E., 84 George Street
1840 *Stevenson, P., philosophical-instrument maker, 5 Forrest Road
1847 *Stevenson Thomas, C.E., F, R.S.E., 84 George Street
1863 Stewart, A. Duncan, C.E., 19 Landsdowne Crescent
1869 Stewart, James Lawson, architect, Carluke
1850 *Stewart, J. W., C.E., 13 Young St.
1865 Stewart, Neil, artist, 11 W. Richmond Street
1864 Strong, Thomas, W.S., 2 Grosvenor Street
1857 Sturrock, John, jun., 3 Queen's Crescent, Newington
1868 Sutter, Archibald, C.E., 9 Manor Pl.
1846 *Swan, Prof. Wm., F.R.S.E., St Andrews
1858 Swann, J. R., builder, 21 Leith Walk

1858 Taplin, Thomas, M.D.
1862 *Tawse, John Wardrop, W.S., 49 Queen Street
1851 *Tennant, Charles, St Rollox, Glasgow
1851 *Tennant, John, St Rollox, Glasgow
1860 Thomson, Alex., teacher, 5-A George Square
1860 *Thomson, Charles W., C.A., 9 Blenheim Place
1863 *Thomson, R. W., C.E., F.R.S.E., 3 Moray Place
1839 *Thomson, W. T., F.R.S.E., 3 George Street
1858 *Tod, James, advocate, 56 Northumberland Street
1861 Tod, James, engraver, 3 St James' Square
1856 Tod, John, engineer, 29 Leith Walk
1846 *Trevelyan, Arthur, of Pencaitland, Tyneholm, Tranent
1840 *Trevelyan, Sir Walter C., Bart., F.R.S.E., Wallington, Newcastle-on-Tyne
1864 Trotter, Alexander, teacher, 59 George Street
1869 Tunny, James Good, photographer, 93 Princes Street
1840 *Turnbull, W., F.R.S.E., accountant, Royal Bank, 14 Landsdowne Cres.
1822 *Tweeddale, The Most Noble George, Marquis of, K.T., F.R.S.E., Yester House, Gifford

1840 *Walker, William, surgeon and oculist, 47 Northumberland Street
1859 Wallace, Alex., M.A., assist.-observer, Royal Observatory
1856 Waterston, George, jun., stationer, 56 North Hanover Street
1866 *Watherston, James, builder, 8 Charlotte Place
1866 *Watherston, William, builder, 8 Charlotte Place
1840 *Watson, Henry George, C.A., 123 George Street
1860 *Watson, John Kippen, F.R.S.E., trea. and manager, Edin. Gas-Light Company, 25 Waterloo Place
1850 *Webster, Andrew, S.S.C., 3 Forth Street
1865 Welsh, Richd., coppersmith, 4 Queens' Place, Greenside
1861 *Whimster, T., gas-engineer, Perth
1867 Whitehead, John, S.S.C., 15 St Andrew Square
1846 *Whitelaw, James, watchmaker, 30 W. Register Street
1867 Whytock, A., merchant, 9 George Street
1838 *Wilkie, John, of Foulden, Berwick-upon-Tweed.
1851 *Willet, John, C.E., Aberdeen Railway
1867 Wilson, James T., manufacturing-chemist, Restalrig House
1858 Wilson, John, coalmaster, South Bantaskine, Falkirk
1859 Wilson, John, F.R.S.E., Professor of Agriculture, College
1868 Wilson, Robert, engineer, Patricroft
1867 Wilson, Thos., teacher, Roberton, by Hawick
1871 Winton, John G., C.E., 1 John Street, Portobello
1860 Wishart, Edward, merchant, 3 Lavrock Bank Terrace, Leith
1872 Wormald, Joseph Dawson, W.S., 8 Middleby Street
1861 Wright James, 13 Ainslie Place

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1859 Wylie, J. S., 5 Viewforth Place

1853 *Young, James, Esq. of Kelly, F.R.S.E., Limefield, West Calder

1859 Young, James, M. D., 36 Castle Street

1861 Younger, Robt., brewer, Croft-an-righ

TOTAL ORDINARY FELLOWS, 388.

The following ORDINARY FELLOWS are ordered to remain, till they return to Scotland, in the following

SUSPENSE LIST.

1859 Richard S. Culley, telegraph-engineer, General Post-Office, London
1868 Henry Dixon, New South Wales
1860 Captain Sir Wm. Hamilton, Bart., Royal Artillery, Simla
1868 N. B. M'Dermott, Jamaica
1862 A. T. Machattie, Ph.D., Ontario Chemical Works, London, Canada West
1870 John Menzies, C.E., Landberis
1846 Mungo Ponton, F.R.S.E., 3 Arlington Villas, Cliton
1854 J. T. Thomson, C.E., Goverment Surveyor, Otago
1854 Dr Daniel Wilson, Professor, Toronto, Canada TOTAL, 9.

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APPENDIX (V.)

NOTE OF THE ORDINARY COURSE OF PROCEDURE FOR THE INFORMATION OF AUTHORS OF COMMUNICATIONS.

1. The Society receives and considers Communications on all subjects connected with the Useful Arts, and on Collateral subjects, from strangers as well as from Members.

2. Communications must be transmitted to the Secretary, with whom, in the first instance, the responsibility of definite acceptance lies.

3. Should the Secretary hesitate as to the acceptance of a Communication he submits it to the Council, and acts on their instructions.

4. Communications intended to be preserved, must be written on foolscap paper, with an inch margin all round; and the accompanying drawings should, if possible, be on the size of imperial drawing paper, with a similar margin.

5. As soon as the Billets intimating any Communication or Report are circulated, the Fellows of the Society are entitled to peruse the same if in the Secretary's hands.

6. In general, though not always, the Society refers the Communication to a Committee.

7. When the Committee's Report is received, intimation is made to the Author, and the Report is open to his inspection.

8. When the Report is read, it is competent for the Society again to discuss the whole subject, to amend or adopt the Report, or to recommit the matter.

9. At the end of the Session a Publication-Committee is appointed to consider the Communications and Reports, and to decide as to whether they should be printed, and how. Plates or Woodcuts to be at the expense of the Author.

10. A Prize-Committee is also appointed to award Prizes to such of the Communications as may appear to be deserving thereof. In making these awards it is understood that originality, ingenuity, and UTILITY are principally considered. The award of the Prize Committee is final, and subject to no remark of approval or disapproval.

11. It is understood that no Member having any interest in any one of the Communications shall be named for the Prize Committee, and as the Secretary is *ex officio* convener thereof, his communications are not submitted for their consideration.

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